IRC:SP:128-2020

URBAN ROADS MANUAL

INDIAN ROADS CONGRESS
2020

URBAN ROADS MANUAL

Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

DECEMBER, 2020

Price : ₹ 1200/-
(Plus Packing & Postage)

IRC:SP:128-2020
First Published : December, 2020

(All Rights Reserved. No part of this publication shall be reproduced, translated or transmitted in any form or by any means without the permission of the Indian Roads Congress)

Printed at India Offset Press, Delhi - 110 064
600 Copies

CONTENTS

S. No. Description **Page No.**

Personnel of the Highways Specifications and Standards Committee i-ii

Introduction 1

Chapter 1 Urban Transport 3

1.1 Urbanization and Transport in India 3
1.2 Status and Role of Road Infrastructure in India 4
1.3 Objectives of Urban Transport and Road Infrastructure 5
1.3.1 Passenger Movement 6
1.3.2 Freight 6
1.4 Universal Accessibility 6
1.5 Smart Cities 6
1.6 Land Use and Transport Integration 7
1.6.1 Mobility Planning 8

Chapter 2 Planning and Development of Urban Roads and Streets 9

2.1 Introduction 9
2.2 Classification of Urban Roads and Streets 9
2.2.1 Definition 9
2.3 Design Principles, Objectives and Street Components 10
2.3.1 Design Principles 10
2.3.2 Design Objectives 10
2.3.3 Street Components and Definitions 10
2.4 Space Standards 12
2.5 Functions and Planning Considerations 12
2.6 Transport Network Planning 18
2.6.1 Network Planning Principles 18
2.6.2 Urban Road Network Pattern 18
2.6.3 Existing Urban Road Network and Retrofitting 18
2.6.4 Urban Road Network for Greenfield Development 18
2.7 Principles of a Pedestrian Network 19
2.8 Principles of a Non-Motorized Vehicle Network 19
2.9 Principles of a Public Transport Network 19
2.10 Multi-modal Integration 19
2.11 Principles for Intersections, Interchanges and Traffic Rotaries 20
2.12 Principles of Parking Management 20
2.13 Principles of Street Vending Management 20
2.14 Access Management 20
2.14.1 Access Management Principles 20
2.14.2 Service Roads 20
2.15 Street Design and Implementation Process 21

S. No. Description Page No.

Chapter 3 Geometric Design Standards 22

3.1 Introduction 22
3.2 Design Controls 22
3.3 Cross-Sectional Elements 23
  3.3.1 Footpath (Sidewalk) 23
  3.3.2 Non-Motorized Vehicle Tracks 23
  3.3.3 Road Width and Design Traffic Volumes 23
  3.3.4 Carriageway Width 24
  3.3.5 Kerb and Kerb Ramp 24
  3.3.6 Medians 24
  3.3.7 Verge 25
  3.3.8 Street Lighting 25
  3.3.9 Typical Cross Sections 25
3.4 Camber 30
  3.4.1 Camber for Carriageway 30
  3.4.2 Camber for Shoulders 31
3.5 Sight Distance 31
  3.5.1 Stopping Sight Distance 31
  3.5.2 Headlight Sight Distance for Valley Curves 31
3.6 Horizontal Alignment 32
  3.6.1 Super Elevation 32
  3.6.2 Minimum Curve Radius 33
  3.6.3 Set-back Distance at Horizontal Curves 33
  3.6.4 Transition Curves 33
  3.6.5 Widening of Carriageway on Curves 35
3.7 Vertical Alignment 35
  3.7.1 Gradient 35
  3.7.2 Vertical Curves 35
3.8 Co-ordination of Horizontal and Vertical Alignments 37
3.9 Lateral and Vertical Clearances 37
3.10 Design of Public Utilities 38
3.11 Topographical Data 38
3.12 Geometric Design Software 39

Chapter 4 Intersections and Interchanges 41

4.1 Introduction 41
4.2 Intersections 41
  4.2.1 Types 41
  4.2.2 Basic Design Principles 42
4.3 Roundabouts 44

S. No. Description Page No.

4.4 Interchanges 46
 4.4.1 Introduction 46
 4.4.2 Typology of Interchange 47
 4.4.3 Planning and Design considerations for Interchange 47
 4.4.4 Interchange Selection Parameters 48
 4.4.5 Study of Physical Conditions 49
 4.4.6 Safety Considerations for Non-Motorized Vehicles (NMV) 50
 4.4.7 Design 50

Chapter 5 Pedestrian Facilities 51
5.1 Footpaths 51
5.2 Pedestrian Amenities 60
5.3 Underpasses 64
5.4 Foot over Bridges 64
5.5 Other Requirements 64
 5.5.1 Bus Stops 64
 5.5.2 Taxi/Auto Rickshaw Stand 66
 5.5.3 Public Toilet 66
5.6 Lighting 67

Chapter 6 Cycle Tracks 69
6.1 NMV Infrastructure 69
6.2 Design Standards 70
 6.2.1 NMV Lane Design Considerations 70
 6.2.2 Width of Cycle Track 71
 6.2.3 Cross-Section 71
6.3 Other Design Elements 71
 6.3.1 Vehicle Types 71
 6.3.2 Speed Range 72
 6.3.3 Clearances and Widths 72
 6.3.4 Coherence 73
 6.3.5 Directness 74
 6.3.6 Attractiveness 74
 6.3.7 Safety and Security 74
 6.3.8 Comfort 74
6.4 Treatment at Intersections 74
6.5 Treatment at Grade Separators 75

Chapter 7 Pavements: Design, Construction and Maintenance 76
A. Design 76
7.1 General 76
7.2 Concept 76

S. No.	Description	Page No.
7.3	New Pavement Design	77
7.3.1	Flexible Pavements	77
7.3.2	Philosophy of Flexible Pavement Design	78
7.3.3	Porous Asphalt Pavements	80
7.3.4	Stone Matrix Asphalt	80
7.3.5	Rigid Pavements	80
7.3.6	Principles of Rigid Pavement Design	81
7.3.7	Factors Governing Design of Concrete Pavement	82
7.3.8	Concrete Block Pavements (CBP)	82
7.3.9	Composite Pavements	84
7.3.10	Whitetopping	84
7.3.11	Evaluation of Existing Pavement for Whitetopping	86
B. Construction		86
7.4	Specifications	86
7.5	Materials	86
7.6	Materials for Non-Motorised Vehicle (NMV) Lane	87
7.7	Recycling of Bituminous Pavements	87
C. Maintenance		89
7.8	Need for Pavement Maintenance	89
7.9	Planning for Maintenance	90
7.9.1	Modes of Deterioration of Pavements and Level of Assessment for Maintenance	90
7.9.2	Assessment of Maintenance Needs for Bituminous Roads	90
7.9.3	Assessment of Concrete Maintenance Needs	92
7.10	Devices for Measuring Surface Deflection	92
7.11	Road Asset Management System and Coordination with Utility Agencies	92
Chapter 8 Drainage		94
8.1	Introduction	94
8.2	Road Surface Drainage	94
8.3	Appurtenants for Discharge of Storm Water Drains	95
8.4	Storm Water Management and Appurtenances	97
8.4.1	Infiltration	98
8.4.2	Detention and Retention Facilities	99
8.4.3	Functional Requirements of Drains	99
8.4.4	Disposal of Storm Water	100
8.5	Sub surface Drainage	100
8.5.1	Drainage of Sub surface Water	101
8.5.2	Aggregate Filters	101

S. No. Description Page No.

8.5.3 Fabric Filters 102
8.6 Disposal of Acceptable Quality of Storm Water 102
8.7 Drainage of Storm Water in Special Locations 102
8.7.1 Flyovers and Bridges 102
8.7.2 Foot of Flyovers 102
8.7.3 Vehicular Subways 103
8.7.4 Rotaries 103
8.7.5 Retail Outlets 103
8.7.6 Intersections 103
8.8 Ground Water Recharging 103
8.9 Maintenance of Drains 104
8.10 Broad Checklist for Maintenance of Drains 104
8.11 Geographical Information System – Master plan 104

Chapter 9 Bridges and Culverts 105

9.1 Introduction 105
9.2 Classification 105
9.3 Geophysical Investigations 105
9.4 General Design Requirement 105
9.4.1 Culverts 105
9.4.2 Bridges 106
9.4.3 Other Design Considerations 109
9.4.4 Determination of Design Discharge 111
9.4.5 Determination of Afflux 112
9.4.6 Freeboard 112
9.4.7 Vertical Clearance over HFL 112
9.4.8 Bridge Foundation 113
9.4.9 Bridge Substructure 113
9.4.10 Bridge Superstructure 114
9.4.11 Drainage 114
9.4.12 Retaining Walls 114
9.4.13 Bearings 114
9.4.14 Expansion Joints 114
9.4.15 Wearing Coat 115
9.4.16 Railings, Parapets and Guide Posts 115
9.4.17 River Training and Protection Works 115
9.5 Performance Requirements 116
9.6 Constructability Considerations 116
9.7 Provision for Utilities 117
9.8 Aesthetics 117

S. No. **Description** **Page No.**

9.9 Operation and Maintenance 117

Chapter 10 Grade Separators, Elevated Roads and Road Over/Under Bridges 119

10.1 Introduction 119
10.2 Type of Facility 119
10.3 Planning and Design of Grade Separators and Elevated Roads 119
10.4 Traffic Analysis 121
10.5 Alignment and Layout 121
10.6 Geometric Configuration 121
10.7 Land Requirement 122
10.8 Relocation of Utility Services and Removal of Trees 122
10.9 Acquisition of Land and Structures 122
10.10 Services allowed to be carried on the Elevated Superstructures 123
10.11 General Features and Geometric Standards 123
10.12 Construction Methodology and Structural Forms 124
10.13 Substructures 126
10.14 Design Parameters 127
10.15 Materials for Construction and Specifications 127
10.16 Loads 128
10.17 Minimum Dimensions 128
10.18 Design for Continuity 128
10.19 Approaches 128
10.20 Approaches in Urban Locations 128
10.21 Utilization of Space below 129
10.22 Retaining Walls and Return Walls 129
10.23 Reinforced Soil Structures 129
10.24 Inspection and Maintenance 129
10.25 Access for Inspection 130
10.26 Road Subway 130
10.27 Road Over and Under Bridge 131

Chapter 11 Urban Tunnels 132

11.1 Background 132
11.2 Classification 132
11.3 Distinctive Features 132
11.4 Planning 133
11.5 Investigations 136
11.6 Construction Methodology 138
  11.6.1 Soft Ground Tunneling 138
  11.6.2 Rock Tunnels 138
  11.6.3 Cut and Cover Tunnels 138

S. No. **Description** **Page No.**
11.7 Ventilation 138
11.8 Lighting 139
11.9 Safety during Construction 139
11.10 Operation and Maintenance 140
11.11 Some Case Studies 140
Chapter 12 Quality Control in Construction 141
12.1 Introduction 141
12.2 Pre-Requisite 141
12.3 Earth Work (Embankment and Subgrade Materials) 142
12.4 Granular Sub-bases (GSB) 142
12.5 Wet Mix Macadam 143
12.6 Bituminous Bound Bases and Surface Courses 144
  12.6.1 Bituminous Surfacing for Low Volume Roads 147
12.7 Cement Concrete Pavements 147
12.8 Recycling of Bituminous Pavements 147
12.9 Tests and their Frequencies 148
12.10 Rectification of Deficiencies 148
Chapter 13 Environmental and Social Safeguards 149
13.1 Introduction 149
13.2 Environmental Impacts of Roads 150
13.3 Prevention and Mitigation Measures 150
  13.3.1 Promote Land-use and Transport Integration 151
  13.3.2 Conduct Environment and Social Impact Assessments 152
  13.3.3 Ecologically Sensitive Zones and Biodiversity Rich Areas 152
  13.3.4 Encourage Low Carbon Transport 152
  13.3.5 Integrate Adaptation Measures with Engineering Specifications 153
  13.3.6 Road Construction and Energy Conservation 155
  13.3.7 Leverage Road Construction and Design to Improve Water Security 155
  13.3.8 Improve Water Efficiency during Road Construction 157
  13.3.9 Use of Recycled Waste Material and Waste Management 158
13.4 Monitoring and Evaluation 158
Chapter 14 Lighting 159
14.1 Background 159
14.2 Definitions 159
14.3 Selection of Lighting Level 160

S. No.	Description	Page No.
	14.3.1 Lighting requirements for different Categories of Roads and Streets	160
	14.3.2 Luminaries Selection	162
	14.3.3 Classification of Lighting	163
14.4	Lighting using High Mast for Junction and Toll Plaza	164
14.5	Other Important Factors	168
14.6	Aesthetics and Durability	168
14.7	Calculation of Performance	169
14.8	Special Provisions for Lighting for Pedestrians	170
14.9	Key Design Guidelines	171
14.10	Fixtures Light Distribution	172
	14.10.1 Full Cut-Off	172
	14.10.2 Cut-Off	173
	14.10.3 Semi Cut-Off	173
	14.10.4 Non Cut-Off	173
	14.10.5 Key Design Guidelines	173
14.11	Energy Efficient Lighting	174
14.12	Types of Lamp Technologies	175
14.13	Intelligent Street Lighting Systems for approaching Road towards Railway Stations and Airports	177
14.14	Technical Specifications for Smart Street Lighting	179
14.15	Bus Stop Areas	181
14.16	Lighting for Pedestrians Walkway	182
Chapter 15 Plantation and Landscaping		185
15.1	Introduction	185
15.2	Landscape Approach	185
15.3	Landscape Development Process	185
15.4	Site Inventory and Analysis	186
15.5	Road Alignment and Landscape Impact	187
15.6	Plantation	188
15.7	Plantation Palette and Selection of Species	190
	15.7.1 Tree Species	191
15.8	Plantation Typologies	192
15.9	Protection Measures	193
15.10	Long Term Plans	194
Chapter 16 Safety and Traffic Control Devices		195
16.1	Introduction	195
16.2	Road Signs	195
	16.2.1 Function	195

S. No. **Description** **Page No.**

16.2.2 Classification 196
16.2.3 Placement with respect to Carriageway 197
16.2.4 Orientation 197
16.2.5 Retro-reflective Sheeting 198
16.2.6 Symbols 198
16.3 Pavement Markings 198
16.3.1 Function 198
16.3.2 Material 198
16.3.3 Colour Pattern 199
16.3.4 Visibility 200
16.3.5 Retro-reflectivity 200
16.3.6 Factors influencing Performance 200
16.3.7 Classification 200
16.3.8 Traffic Lane Lines 202
16.3.9 No Overtaking Lines 202
16.3.10 Warning Lines 202
16.3.11 Edge Lines 202
16.3.12 Stop Line Markings 203
16.3.13 Give Way Markings 203
16.4 Road Studs 204
16.4.1 General 204
16.4.2 Colours for Road Studs 204
16.4.3 Solar Road Studs 205
16.4.4 Chevron Markings 205
16.5 Crash Barriers 206
16.5.1 Road Side Barriers 207
16.5.2 Median Barriers 211
16.6 Crash Cushions 215
16.7 Delineators 216
16.7.1 Roadway Indicators 216
16.7.2 Hazard Markers 217
16.7.3 Object Markers 219
16.7.4 Installation of Delineators 219
16.7.5 Maintenance of Delineators 220
16.8 Safety in Construction Zones 220
16.8.1 Context 220
16.8.2 Basic Principles of Work Zone Traffic Management Plans 220
16.8.3 Planning Consideration of Work Zone Traffic Management Plans 221

S. No.	Description	Page No.
16.8.4	Risks of Accidents at Construction Zones	221
16.8.5	Aspects to Manage the Construction Zone	221
16.8.6	Safety Aspects for Workers at Construction Zones	222
16.8.7	Management of Traffic in Construction Zone	222
16.8.8	Elements of Temporary Traffic Control Zone	222
16.8.9	Temporary Structures Safety	222
16.8.10	Preparation of Formwork Plans	224
Chapter 17	**Traffic Calming Measures**	225
17.1	Introduction	225
17.2	Guiding Principles	225
17.3	Classification of Traffic Calming Techniques	225
17.4	Traffic Calming Measures in Urban Areas	226
17.4.1	Vertical Deflections	226
17.4.2	Horizontal Deflections	230
17.4.3	Road Narrowing	231
17.4.4	Central Islands	231
17.5	Traffic Calming at Road Junctions	231
17.5.1	Special Treatments	231
17.5.2	Special Junction Forms	231
17.6	Traffic Calming on Arterial Roads	232
17.7	Eligibility Criteria and Area of Application	233
Chapter 18	**Disaster Management**	235
18.1	Introduction	235
18.2	Disaster Risk in India	235
18.3	Disaster Management	235
18.4	Disaster Resilience	236
18.5	Roads and Disaster Management	236
18.6	Transportation and Disaster Management	237
18.7	Guidelines for Preparedness	237
18.7.1	Risk Assessment	237
18.7.2	Assessment of Scale of Severity	238
18.7.3	Disaster Management Plan	238
18.7.4	Guidelines	239
18.7.5	Transport Planning Level	240
18.7.6	Project Design Level	241
18.8	Guidelines for Disaster Response	242
18.8.1	Guidelines	243
18.9	Guidelines for Restoration Measures (disaster recovery phase)	244
18.9.1	Guidelines	245

S. No. Description Page No.

18.10 Case Studies 245

18.10.1 Chennai Floods (December, 2015) 245

18.10.2 The Great East Japan Earthquake and Tsunami (March, 2011) 247

Chapter 19 Parking Management 249

19.1 Introduction 249

19.2 Key Guiding Principles 249

19.3 Parking Strategies for Different Types of Vehicles 249

19.4 Types of Parking Facilities 250

19.5 Parking Space Requirements 250

19.6 Parking Layouts 251

19.7 Parking Design Considerations 253

19.8 Parking for Persons with Disabilities and Reduced Mobility 255

Chapter 20 Transport Demand Management 257

20.1 Introduction 257

20.2 Key Principles 257

20.2.1 User Pays Principle 257

20.2.2 Sustainable Transport 257

20.2.3 Being Coordinated and Technology-Enabled 258

20.2.4 Being Scientific, Data-Driven and Outcome-Oriented 258

20.3 Key Transport Demand Management Strategies 258

20.4 Public Transport (PT) and Private Shared Mobility (PSM) 258

20.5 Urban Road Design and Parking Management 259

20.5.1 Urban Road Design 259

20.5.2 Parking Management 259

20.6 Financial Incentives and Disincentives 259

20.7 Transit-Oriented Development (TOD) 260

20.8 Urban Freight Movement Management 260

20.9 Employee TDM Measures 260

20.10 Assessing Impacts of TDM Measures 261

Chapter 21 Intelligent Transportation System and Traffic Management 262

21.1 Introduction 262

21.2 Challenges in the Traffic Management and Road Safety 262

21.3 Need for ITS Architecture 262

21.3.1 Logical Architecture 263

21.3.2 Physical Architecture 263

21.3.3 Organizational Architecture 264

21.4 Detection and Data Collection Methods 265

21.4.1 Detection Methods 265

S. No. Description Page No.
21.4.2 Data Collection Methods 266
21.5 ITS for Urban Traffic Management 267
21.5.1 Advanced Traffic Management System (ATMS) 268
21.5.2 Traffic Management Centre (TMC) 269
21.6 Phase for Implementation of ITS 270
Chapter 22 Knowledge Development 271
22.1 Government Initiatives 271
22.2 Emerging R&D Areas 272
22.3 Budgetary Allocations 272
22.4 Institutional Arrangements 273
22.4.1 Institute of Urban Transport, India (IUT) 273
22.4.2 Centers of Excellence 274
22.5 Research Funding Schemes 274
22.5.1 IMPRINT 274
22.5.2 Uchchatar Avishkar Yojana (UAY): Industry-Academia Coordination 275
22.5.3 DST 275
22.5.4 SERB 275
22.5.5 TIFAC 275
22.6 Dissemination 276
Chapter 23 Capacity Building and Skill Development 277
23.1 Context 277
23.2 Key Requirement 277
23.3 Main Areas of Focus 278
23.4 Core Competence 279
23.5 Unified Metropolitan Transport Authority (UMTA) 280
23.6 Skill Development and Training Strategy 280
23.6.1 Target Groups 280
23.6.2 Training Strategy: 280
23.6.3 Skill Development and Training Plan 281
23.6.4 Funds 281
23.6.5 Training Infrastructure and Institutional Architecture 282
23.6.6 Training Areas, Modules and Course Material 282
23.6.7 Skill Development of Contractor Managers, Workers and Equipment Operators 283
Annex 23.1 284
References 286

LIST OF FIGURES

S. No.	Description	Page No.
Fig. 1.1	Modal Splits across City Sizes, Source: MoUD, 2008	3
Fig. 1.2	Avoid-Shift-Improve Approach	4
Fig. 1.3	Smart Solutions, Source: MoUD	7
Fig. 1.4	Mode Priority in Street Design	8
Fig. 2.1	Slow and Fast Zones of a Right of Way	11
Fig. 2.2	Design and Implementation Process for Existing Street	21
Fig. 3.1	Typical Cross Section for Arterial Road	26
Fig. 3.2	Typical Cross Section for Sub Arterial Road	27
Fig. 3.3	Typical Cross Section for Collector Street	28
Fig. 3.4	Typical Cross Section for Local Street	29
Fig. 3.5	Typical Cross Section for Urban Expressway	30
Fig. 3.6	Elements of a Combined Circular and Transition Curve	32
Fig. 4.1	Hierarchy of Intersections	41
Fig. 4.2	General Types of Intersections	42
Fig. 4.3	Potential Conflict Points at Intersections	43
Fig. 4.4	Channelizing Islands	43
Fig. 4.5	Staggering of Intersections	43
Fig. 4.6	Geometric Elements of Roundabout	44
Fig. 4.7	Typical Single Lane Roundabout	45
Fig. 4.8	Typical Multi-Lane Roundabout	45
Fig. 4.9	Diverse Types of Interchanges	46
Fig. 4.10	Sight Distance Requirements at Exit Ramps	47
Fig. 4.11	Typical Designs for Entry and Exit Terminals	48
Fig. 5.1	Excessive Height of Kerb makes Footpaths hard to use, and many Pedestrians prefer to walk in the Carriageway	51
Fig. 5.2	Footpaths with a Height of Kerb no more than 150 mm are more likely to be used	51
Fig. 5.3	Footpath Zones	52
Fig. 5.4	Footpaths in Residential and Commercial Zones	53
Fig. 5.5	Minimum Width of a Clear Footpath	54
Fig. 5.6	Pedestrian Zone : Clear Walking Zone is separate from Furniture Zone	55
Fig. 5.7	Footpaths with Levelled Surface is easy to use by Pedestrians	56
Fig. 5.8	Kerb Ramp: Gradient	56
Fig. 5.9	Kerb Ramp with Tactile Pavers	57
Fig. 5.10	Height and Gap Between Bollards	58
Fig. 5.11	Raised Pedestrian Crossing	58
Fig. 5.12	Type of Design of Four Arm Intersection showing Zebra Crossing and Pedestrian Phases	60

S. No.	Description	Page No.
Fig. 5.13	Dustbins on Streets	61
Fig. 5.14	Colour and Contrast	62
Fig. 5.15	Traffic Signal (Left) and Audio Signal (Right)	63
Fig. 5.16	Location of Bus Stops	65
Fig. 5.17	Lighting Directed Downward, Poles Spaced away from Trees	67
Fig. 5.18	Lighting on the Footpath	68
Fig. 6.1	Segregated NMV Track	69
Fig. 6.2	Segregated NMV Lane	70
Fig. 6.3	Tricycle for People with Disability	72
Fig. 6.4	Space Dimension for NMV	73
Fig. 7.1	Typical View of Conventional Flexible Pavement with Different Layers	76
Fig. 7.2	Typical View of Jointed Plain Reinforced Concrete Pavements	77
Fig. 7.3	Typical Cross Section of Concrete Pavement	81
Fig. 7.4	Various Laying Patterns of CBP	83
Fig. 7.5	Overview of Reclamation and Recycling	88
Fig. 8.1	Inclination of Roadside Gutter and Inlets with respect to Flow in Pavement	95
Photo 8.1	Median Opening up to Two Lanes in each Direction	96
Fig. 8.2	Median Opening up to Two Lane in each Direction	96
Fig. 8.3	Drainage Arrangement at Medians (for three lanes or more in each direction)	97
Fig. 8.4	Storm Water Management Chart	98
Fig. 8.5	Typical Selection of Infiltration Pit	99
Fig. 10.1	Traffic Movement at Intersection	120
Photo 10.1	Grade Separated Elevated Roads in Urban Area	120
Photo 10.2	Road Subway	130
Photo 10.3	Road Under Bridge	131
Fig. 11.1	Section of Two Lane Bi-Directional Traffic Tunnel	135
Fig. 11.2	Section of Two Lane Uni-Directional Traffic Tunnel	135
Fig. 11.3	Section of Three Lane Uni-Directional Traffic Tunnel	135
Fig. 11.4	Section of Four Lane Uni-Directional Traffic Tunnel	136
Fig. 11.5	Section of Four Lane Bi-Directional Traffic Tunnel	136
Fig. 13.1	Roads Flooded during Chennai Floods	149
Fig. 14.1	Types of Lighting Arrangements	162
Fig. 14.2	Elements of Lighting Installation	163
Fig. 14.3	Typical Base Compartment of High Mast	165
Photo 14.3	Luminaries Selection (Flood Light/Street Light)	166
Fig. 14.4	Calculation Points on Relevant Area	169
Fig. 14.5	Light Pole Placement	172
Fig. 14.6	Light cut-off with respect to Trees	172

S. No.	Description	Page No.
Fig. 14.7	Light Fixtures	174
Fig. 14.8	RF based Individually Addressable Streetlight Management System	179
Fig. 14.9	Luminaire Selection	182
Fig. 14.10	Street Lighting on Narrow Streets	183
Fig. 14.11	Street Lighting on Wide Streets	183
Fig. 14.12	Placing of Street Lights should be placed coordinated with Trees to avoid Dark Spots	184
Fig. 15.1	Typical Road Cross-section with Planting, Swales, Site Furniture, Carriageway and Retaining Walls	186
Fig. 15.2	Visibility to the surroundings depends on the Planting Structure	189
Fig. 15.3	Views to distinct natural features can create Scenic Drives	190
Fig. 15.4	Typical Urban Road Cross- section with Median and Roadside Plantation	193
Fig. 16.1	Placement of Signs with respect to Carriageway	197
Fig. 16.2	Two Lane Bi-Directional Road	201
Fig. 16.3	Lane Divided Carriageway	201
Fig. 16.4	Stop Line Markings with Stop Sign	203
Fig. 16.5	Give Way Marking with Give Way-Sign	203
Fig. 16.6	Road Studs	204
Fig. 16.7	Solar Studs	205
Fig. 16.8	Road Studs for Diagonal & Chevron Marking	206
Fig. 16.9	Types of Safety Barriers	207
Fig. 16.10	Bridge Approach Barrier Criteria	208
Fig. 16.11	Typical Details of 'W' Structural Elements	209
Fig. 16.12	Typical Details of Thrie Beam Structural Elements	210
Fig. 16.13	Typical details of Wire Rope Safety Barrier	210
Fig. 16.14	Typical details of W Beam Median Barrier	211
Fig. 16.15	Typical Details of Thrie Beam Median Barrier	212
Fig. 16.16	Typical Details of Interwoven Wire Rope Safety Barrier	212
Fig. 16.17	Median Wire Road Safety Barrier	213
Fig. 16.18	Road Side/Median Barrier Cast-In-Situ Design	213
Fig. 16.19	Lateral Clearance for Different Barriers	214
Fig. 16.20	Crash Cushions: Sand-filled Barrels	215
Fig. 16.21	Typical View of Delineator	216
Fig. 16.22	Hazard Marker	218
Fig. 16.23	Temporary Traffic Control Zone	223
Fig. 17.1	Classification of Traffic Calming Techniques	225
Fig. 17.2	Geometric Details of Circular Road Hump	227
Fig. 17.3	Geometric Details of Trapezoidal Road Hump	228
Fig. 17.4	Rumble Strip (not to scale)	228

S. No.	Description	Page No.
Fig. 17.5	Road Bump in Narrow Residential Street	229
Fig. 17.6	Speed Table	229
Fig. 17.7	Uneven Road Surface in IIT Delhi	230
Fig. 17.8	Chicane Island to deflect the Traffic	230
Fig. 17.9	Design to facilitate Mid-Block Crossing by Pedestrians	231
Fig. 17.10	Raised Areas for Pedestrians	232
Fig. 17.11	Transverse Bar Marking as an Alerting Measure	232
Fig. 17.12	Transverse Bar Marking with Stricter Compliance	233
Fig. 18.1	Disaster Management Continuum	236
Fig. 18.2	Flooding in Chennai (2015), Source: Indian Air Force	246
Fig. 18.3	Image Source: Yoshitaka Motoda	247
Fig. 18.4	Image Source: Toshitaka Motoda	247
Fig. 18.5	Comb Formation Image Source: Yoshitaka Motoda	248
Fig. 19.1	Parking Layout Design for Two Wheelers	251
Fig. 19.2	Parking Layout Design for Low Floor Buses	251
Fig. 19.3	Parking Layout Design for Cars	252
Fig. 19.4	Parking Layout Design for Three Wheelers	252
Fig. 19.5	Parking Layout Design for Trucks	253
Fig. 19.6	On-Street Parking Planning Detail	253
Fig. 19.7	On-Street Parking Detail at Pedestrian Crossing	254
Fig. 19.8	On-Street Parking Detail for 2-Wheeler on Narrow Street	254
Fig. 19.9	Buffer Detail between On-Street Parking and Cycle Track	254
Fig. 19.10	Common Access Aisle	255
Fig. 19.11	Width of Accessible Parking	255
Fig. 19.12	International Symbol of Accessibility	256
Fig. 21.1	Logical Architecture Framework (Source: U.S. Department of Transportation)	263
Fig. 21.2	ITS Architecture (Source: U.S. Department of Transportation)	264
Fig. 21.3	Operation of RFID	267
Fig. 21.4	ATMS Data Collection System	268
Fig. 21.5	Concept of Traffic Management Control Centre	269

LIST OF TABLES

S. No.	Description	Page No.
Table 2.1	Recommended Land Widths for Roads in Urban Areas	12
Table 2.2	Functions and Planning Considerations for Urban Roads and Streets in New Areas	13
Table 2.3	Planning Considerations for Existing Urban Roads and Streets	15
Table 3.1	Design Speeds (km/h)	23
Table 3.2	Recommended Carriageway Widths	24
Table 3.3	Camber for Carriageways	30
Table 3.4	Safe Stopping Sight Distance for Various Speeds	31
Table 3.5	Radii beyond which Super Elevation is not required	33
Table 3.6	Minimum Radii of Horizontal Curves	33
Table 3.7	Minimum Transition Lengths (in metres) for Different Speeds and Curve Radii	34
Table 3.8	Extra Width of Pavement at Horizontal Curves	35
Table 3.9	Recommended Minimum Gradients	35
Table 3.10	Minimum Length of Vertical Curves	36
Table 4.1	Guiding Principle for Assessing Feasibility of Interchange	49
Table 5.1	Capacity of Footpath (Uninterrupted Walking Zone)	54
Table 5.2	Required Width of Uninterrupted Walking Zone as per Predominant Land Uses along a Street Segment	54
Table 6.1	Width of Cycle Track (Source: CROW Manual)	71
Table 6.2	Dimensions of Cycles	72
Table 6.3	Clearances and Widths (in mm)	73
Table 6.4	Accident Severity and Intersection Solutions	75
Table 7.1	Whitetopping	85
Table 7.2	Recycling Options	89
Table 7.3	Pavement Distress Based Rating for Urban Roads	91
Table 7.4	Serviceability Indicators for Urban Roads	91
Table 9.1	Design Parameters	107
Table 9.2	Vertical Clearance over HFL	113
Table 10.1	Geometric Design Standards: Key Requirements	123
Table 11.1	Legend for Symbols Used in Sketches	134
Table 12.1	Density Requirements of Embankment and Sub-grade Materials	142
Table 12.2	Compaction Requirements for Embankment and Sub-grade	142
Table 12.3	Grading for Granular Sub-base Materials	143
Table 12.4	Physical Requirements for Materials for Granular Sub-base	143
Table 12.5	Physical Requirements of Aggregates	143

S. No.	Description	Page No.
Table 12.6	Grading Requirements of Aggregates for Wet Mix Macadam	144
Table 12.7	Physical Requirements of Aggregates	144
Table 12.8	Composition of Dense Graded Bituminous Macadam	145
Table 12.9	Composition of Bituminous Concrete Pavement Layers	145
Table 12.10	Requirements of Mix Design for Dense Graded Bituminous Mix	146
Table 12.11	Minimum Percent Voids in Mineral Aggregate (VMA)	146
Table 12.12	Aggregate Gradation for Close Graded PMC/MSS	147
Table 12.13	Quality Requirements	147
Table 13.1	Impact of Climate Change and Mitigation Approaches	153
Table 14.1	Determination of Uniformity and Lux Level according to type of Roads	160
Table 14.2	Parameter on Luminaire Classification	167
Table 14.3	Technical Specifications for Polymeric Coating	169
Table 14.4	Selection of the arrangements of the Poles	170
Table 14.5	Main Principles of Lighting for Pedestrians	170
Table 14.6	Types of Lighting Fixtures	173
Table 14.7	BIS LED Lighting Standard: (As per BIS 2012)	175
Table 14.8	Types of Lamp Technologies (Source: USAID 2010)	175
Table 14.9	Proposed Automation and Energy Savings Systems	178
Table 14.10	General Function of the System	180
Table 14.11	Street Light Height and Spacing as per Street Type	182
Table 15.1	Landscape Considerations	187
Table 15.2	Key Concepts for Planting: Do's and Don'ts	191
Table 16.1	Height and Clearance required for Sign Placement	197
Table 17.1	Recommended Radii and Chord Lengths for Circular Humps (assumed rise = 10 cm)	226
Table 17.2	Recommended Ramp Lengths and Gradients for Trapezoidal Humps	227
Table 17.3	Traffic Calming Techniques for Arterial Roads	233
Table 17.4	Traffic Calming Techniques for Collector Roads	234
Table 17.5	Traffic Calming Techniques for Residential Streets	234
Table 17.6	Traffic Calming Techniques in High Pedestrian Activity Zones	234
Table 19.1	Parking Space Requirement	250
Table 19.2	Equivalent Car Spaces (ECS)	251

PERSONNEL OF THE HIGHWAYS SPECIFICATIONS AND STANDARDS COMMITTEE

(As on 06.12.2019)

1	Pandey, I.K. (Convenor)	Director General (Road Development) & Special Secretary to Govt. of India, Ministry of Road Transport and Highways, New Delhi
2	Balakrishna, Y. (Co-Convenor)	Additional Director General, Ministry of Road Transport and Highways, New Delhi
3	Kumar, Sanjeev (Member Secretary)	Chief Engineer (R) S, R & T, Ministry of Road Transport and Highways, New Delhi

Members

4	Behera, Bijan Kumar	Engineer-in-Chief (Civil) (Retd.), Odisha
5	Bose, Dr. Sunil	Head (Retd.), FPC Division, Central Road Research Institute, New Delhi
6	Chandra, Dr. Satish	Director, Central Road Research Institute, New Delhi
7	Gupta, D.P.	DG(RD) & AS (Retd.), Ministry of Surface Transport, New Delhi
8	Jain, R.K.	Chief Engineer (Retd.), PWD Haryana
9	Kapila, K.K.	Chairman & Managing Director, ICT Pvt. Ltd., New Delhi
10	Kukrety, B.P.	Associate Director, CEG Ltd., New Delhi
11	Kumar, Dr. Mahesh	Engineer-in-Chief (Retd.), PWD (B&R) Haryana
12	Lal, Chaman	Engineer-in-Chief (Retd.), PWD Haryana
13	Meena, H.L.	Secretary (Retd.), PWD Rajasthan
14	Nashikkar, J.T.	Secretary (Retd.), PWD Maharashtra
15	Nirmal, S.K.	Secretary General, Indian Roads Congress, New Delhi
16	Parida, Prof. (Dr.) M.	Deputy Director, Indian Institute of Technology, Roorkee
17	Patel, S.I.	Secretary (Retd.), PWD (Roads and Buildings) Gujarat
18	Prasad, R. Jai	Engineer-in-Chief (Retd.), PWD & Bangalore Mahanagar Palike, Karnataka
19	Rawat, M.S.	Executive Director, AECOM India Pvt. Ltd.
20	Reddy, Dr. K.S. Krishna	Chief Project Officer, Karnataka State Highways Improvement Project, Karnataka
21	Reddy, I.G.	Engineer-in-Chief (NH, CRF & Buildings), PWD Hyderabad
22	Reddy, Prof. (Dr.) K.S.	Professor, Indian Institute of Technology, Kharagpur
23	Sharma, S.C.	DG(RD) & AS (Retd.), Ministry of Road Transport and Highways, New Delhi
24	Shrivastava, A.K.	Additional Director General (Retd.), Ministry of Road Transport and Highways, New Delhi
25	Singh, Nirmaljit	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
26	Sinha, A.V.	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi

27	The Chief Engineer (Basar, Toli)	PWD Arunachal Pradesh
28	The Addl. DGBR (North-West) (Kumar, Anil)	Border Roads Organisation, New Delhi
29	The Director (Tech.) (Pradhan, B.C.)	National Rural Infrastructure Development Agency, New Delhi
30	The General Manager (Projects) (Retd.) (Kaul, Satish)	National Highways and Infrastructure Development Corporation, New Delhi
31	The JICA Expert (Kitayama, Michiya)	Japan International Cooperation Agency, New Delhi
32	The Member (Projects) (Pandey, R.K.)	National Highways Authority of India, New Delhi
33	The Professor (Chakroborty, Dr. Partha)	Indian Institute of Technology, Kanpur
34	The Secretary (Vasava, S.B.)	Roads and Buildings Department, Gujarat
35	The Secretary (Roads) (Joshi, C.P.)	PWD Maharashtra
36	The Secretary (Tech.) (Tickoo, Bimal) (Retd.)	Roads and Buildings Department, Jammu & Kashmir
37	The Special Director General (Retd.) (Bansal, M.C.)	CPWD, Nirman Bhawan, New Delhi
38	Venkatesha, M.C.	Consultant
39	Wasson, Ashok	Member (Tech.) (Retd.), National Highways Authority of India, New Delhi

Corresponding Members

1	Jaigopal, R.K.	MD, Struct Geotech Research Laboratories (P) Ltd., Bengaluru
2	Justo, Prof. (Dr.) C.E.G.	Professor (Retd.), Emeritus (*Expired in June, 2019*)
3	Veeraragavan, Prof. (Dr.) A.	Professor, Indian Institute of Technology, Madras

Ex-Officio Members

1	President, Indian Roads Congress	(Basar, Toli), Chief Engineer, PWD Arunachal Pradesh
2	Director General (Road Development) & Special Secretary to Govt. of India	(Pandey, I.K.), Ministry of Road Transport and Highways, New Delhi
3	Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

URBAN ROADS MANUAL

INTRODUCTION

The task of preparation of Urban Roads Manual was taken up by Urban Roads and Streets Committee (H-8) during the tenure 2015-17. The initial draft prepared by the subgroup under the Chairmanship of Shri D.P. Gupta was discussed in various meetings of H-8 Committee and was finalized in its meeting held on 18.08.2017. The Highways Specifications and Standards Committee (HSS) in its meeting held on 24.10.2017 decided that this draft document needs to be reviewed. The draft was modified and was placed before the Executive Committee (EC). Considering the importance of the document, the EC in its meeting held on 02.11.2017 decided to place this document before Council. The 213th Council deliberated the draft document in its meeting held on 03.11.2017 and authorized EC to take final call about its publishing. The EC in its meeting held on 27.10.2018 referred back the draft document to H-8 Committee for further modifications. In the meanwhile, the H-8 Committee was reconstituted for the tenure 2018-20. Thereafter, the H-8 Committee constituted a subgroup for finalizing the draft document under the Chairmanship of Shri S.K. Marwah comprising Shri D.P. Gupta, Dr. Ch. Ravi Sekhar, Shri Vikas Thakar, Shri Amit Bhatt, Ms. Shreya Gadepalli, Ms. Anjlee Agarwal, Shri R.K. Jaigopal, Shri R. Jai Prasad, Prof. Rajat Rastogi and Dr. Devesh Tiwari. The draft was again discussed and further modified in the various meetings of H-8 Committee and was approved in its meeting held on 13.11.2019 for placing before the HSS Committee.

The composition of H-8 Committee is given below:

Parida, Prof. (Dr.) M.	....	Convenor
Marwah, S.K.	....	Co-Convenor
Ravi Sekhar, Dr. Ch.	....	Member-Secretary

Members

Agarwal, Anjlee
Bhatt, Amit
Gadepalli, Shreya
Gupta, D.P.
Jaigopal, R.K.
Kumar, Dinesh
Kumar, Dr. Mahesh
Kumar, Dr. Pawan
Kumar, Sanjeev
Prasad, R. Jai
Sharan, G.
Singh, Nirmaljit
Thakar, Vikas
Tiwari, Dr. Devesh
BRO (Agarwal, A.K.)
CPWD (Kumar, Anant)
IIT Bombay (Rao, Prof. (Dr.) K.V.K.)
IIT Delhi (Rao, Prof. (Dr.) K.R.)
IIT Roorkee (Rastogi, Prof. (Dr.) Rajat)
MoRTH (Chamargore, U.J.)
MoRTH (Sharma, Narendra)

Corresponding Members

Gupta, Dr. Sanjay

Mishra, Manikant

Raju, Dr. Phani

Rawat, M.S.

Sharma, Rajiv

Ex-Officio Members

President,
Indian Roads Congress

Director General
(Road Development) & Special
Secretary to Govt. of India

Secretary General,
Indian Roads Congress

(Basar, Toli), Chief Engineer,
PWD Arunachal Pradesh

(Pandey, I.K.), Ministry of Road
Transport & Highways

Nirmal, Sanjay Kumar

The draft document was reconsidered by the HSS Committee in its meeting held on 06.12.2019. The HSS Committee decided that Convenor, H-8 Committee will modify the document based on written comments and verbal comments offered during the meeting and submit the final document to IRC for placing during the EC and Council meeting. The EC in its meeting held on 19.12.2019 approved the draft document for placing before the Council. The 219th Council in its meeting held on 19.12.2019 at Patna, Bihar considered and approved the document "Urban Roads Manual" for printing.

CHAPTER 1

URBAN TRANSPORT

1.1 Urbanization and Transport in India

In 2011, India's urban population was about 377 million and is projected to increase 1.6 times to around 598 million by 2031 (Report on Indian Urban Infrastructure and Services, HPEC, 2011). Further, India's three largest metropolis, Mumbai, Delhi and Kolkata have a population over 10 million. Five cities - Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune - have over 5 million residents. Cities with a population of more than one million have increased from 35 in 2001 to 53 in 2011 and constitute 43% of the urban population. The number of Class I towns (those with a population above 1 lakh residents) increased from 394 in 2001 to 468 in 2011 and constitute 70% of the total urban population (Census 2011).

Of 7935 towns, the number of Census Towns increased by 186%, whereas the number of statutory towns increased by around 6%. This signifies that a number of rural settlements have attained urban characteristics and are accordingly classified as Census Towns (Census 2011).

This urbanization has put demand on India's infrastructure, especially its transportation and road networks. In the last 25 years, urban India has faced increasing motorization, sprawl, congestion and deteriorating public health. The number of registered motor vehicles increased from 21.4 million in 1991 to 230 million in 2016 (MoRTH 2016). While transportation planning and road engineering has prioritized the movement of private motorized vehicles, the reality is that walking, cycling, public transport and para-transit dominate a majority of trips in Indian cities (see **Fig. 1.1**). These modes account for 47-66% of trips in cities with population up to 0.5 million, around 60-65% of trips in cities with population ranging from 1-8 million and about 80% of trips in cities above 8 million residents. Therefore, urban transport and road infrastructure need to cater for non-motorized and public transport modes as well.

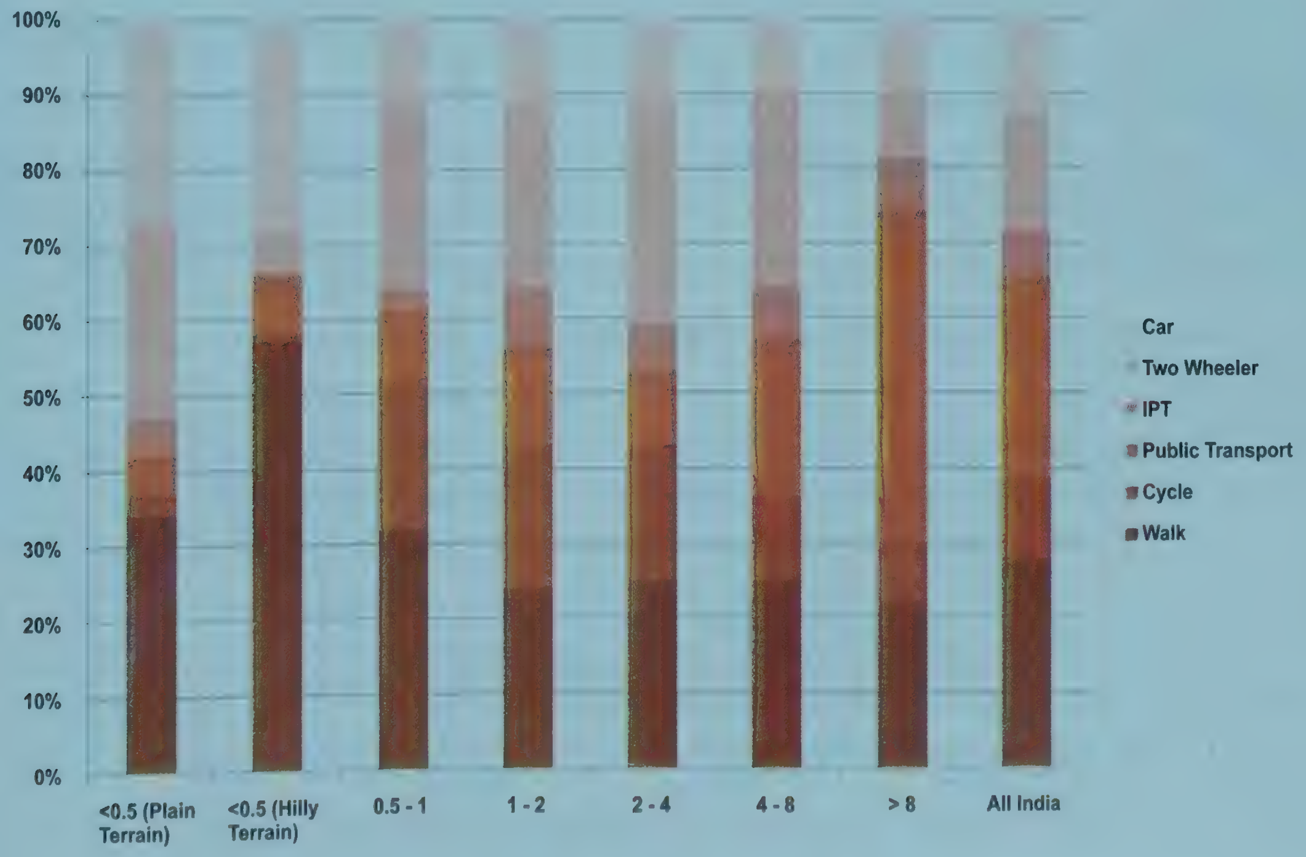


Fig. 1.1 Modal Splits across City Sizes, Source: MoUD, 2008

1.2 Status and Role of Road Infrastructure in India

Roads are an important and core component of any city's transport infrastructure framework. They occupy approximately 20 percent of the total land area in a city (ITDP and EPC, 2011). A city's road network includes all associated facilities i.e. carriageway, footpaths, cycle tracks, pedestrian crossings, bus stops, taxi, auto, cycle rickshaw stands, intersections, street furniture, spaces for street vending, bridges, flyovers, tunnels, facilities for parking, terminals, inter-modal transfer hubs, road markings, signages, traffic signals and other traffic control devices, and service lanes (MoUD, 2014).The planning and design of the road network determines how effectively and efficiently people, goods, and materials move through the city.

However, urban roads also pose safety hazards. They contribute to 42% of total road accidents and around 35% of total road accident deaths (MoRTH, 2017). Pedestrians (13.8%), bicyclists (2.4%) and two wheelers (33%) are the most vulnerable constituting close to 50% of road fatalities. Inadequate facilities for pedestrian and bicycle infrastructure, lack of safe road engineering measures, high vehicular speeds, weak enforcement of existing traffic rules, lack of on-street parking and vending management, and lack of awareness among road users have contributed to this negative externality.

Similarly, it is observed that road transport is responsible for a major portion of carbon dioxide equivalent (MT CO2e) emissions. More emphasis would be needed to review the design philosophy of road network in urban areas to ensure road safety, universal accessibility and environmental sustainability. This can be achieved by reallocating existing road space and designing new urban roads to encourage the use of public and non-motorized transport, and reduce dependence on private motorized vehicles. It requires a people focused approach, one that prioritizes accessibility over mobility (NUTP 2014) for all age groups, gender and physical abilities.

Thus, a shift in the approach is needed with three key strategies, namely, 'Avoid, Shift and Improve' in transport planning as advocated by the Asian Development Bank in its draft 'Action Plan to Make Transport in Developing Countries more climate friendly' and reiterated by the Bellagio Declaration 8, in May 2009. This means 'avoid' increase in travel demand by reducing the number and length of trips. Encourage a shift from personal vehicles to public transport and non-motorized transport modes to reduce energy demand and pollution in cities. Improve strategy to develop and use clean fuels and clean vehicle technology. (See **Fig. 1.2**)

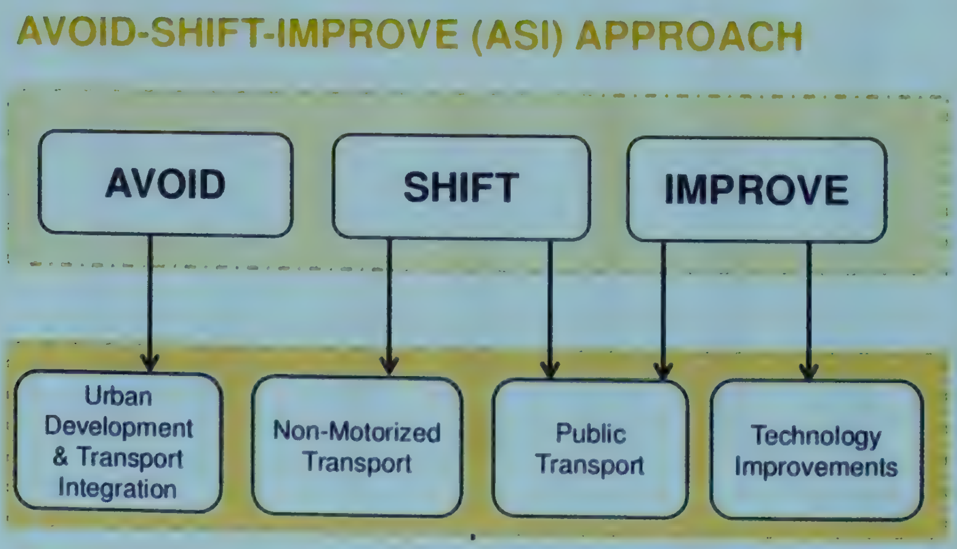


Fig. 1.2 Avoid-Shift-Improve Approach

1.3 Objectives of Urban Transport and Road Infrastructure

Urban transport and road infrastructure can facilitate economic growth and guide the growth of cities and regions. There is an urgent need to conserve energy and land, control pollution and 'greenhouse gas emissions', and to alleviate poverty through equitable allocation of the road space. Urban transport is a significant cause and also a solution to these issues. Hence, planning and management of urban transport services and infrastructure require immediate attention. **Box 1.1** captures some of the key objectives and strategies within the purview of National Urban Transport Policy (2014).

Box 1.1 National Urban Transport Policy: Key objectives and strategies

A. Key Objectives:

- Incorporating urban transportation as an important parameter at the urban planning stage rather than being a consequential requirement.
- Bringing about a more equitable allocation of road space for people, rather than for vehicles.
- Public transport should be citywide, safe, seamless, user friendly, reliable and should provide good ambience with well-behaved drivers and conductors.
- Walk, cycle and public transport should become safe modes of urban transport.
- Introducing Intelligent Transport System for traffic management and enhanced safety.
- Addressing concerns of road safety and trauma response.
- Raising finances through innovative mechanisms.
- Establishing institutional mechanisms for enhanced coordination in planning and management of transport systems.
- Building capacity (institutional and manpower) to plan for sustainable urban transport and establishing knowledge management system that would service the needs of all urban transport professionals, such as planners, researchers, teachers, students, etc.

B. Key Strategies:

- Identify citywide priority networks for walkability, non-motorized vehicles and public transport.
- Enhanced safety for pedestrians and cyclists and other road users of all age groups and gender.
- Universally accessible road network.
- Well-lit streets to enhance safety and security.
- Develop a network of public transport, which is accessible within a 5-minute walking distance.
- On roads and streets with over 3,000 pphpd (persons per hour per direction) in public transport, create dedicated public transport (i.e. bus rapid transit) lanes. Give other forms of priority to public transport (e.g. restricted access to private motor vehicles, traffic signal priority, etc.) on roads and streets where provision of dedicated lanes is not feasible.
- Create "formal" on-street vending areas, especially on major streets and near public transport nodes. Well-planned vending zones can make urban spaces more vibrant, promote social supervision and improve personal safety especially for women's group and children. Vending areas should be positioned to ensure the continuity of cycle tracks and footpaths.
- Allocate space for private motor parking on streets only after providing space for pedestrians, cyclists and public transport.
- Reduced dependence on private motor vehicles for daily use.

1.3.1 *Passenger Movement*

Passenger trips within urban areas are primarily served by walking, cycling and public or intermediate modes of transport. When passenger volumes increase, mass rapid transit systems in the form of bus rapid transit, light rail and/or metro rail systems can be considered.

1.3.2 *Freight*

There needs to be a greater focus on planning for movement of goods in urban areas, since transport of goods will grow with economic development. Goods movement should not affect passenger movement. For optimum use of the urban transportation infrastructure, movement of freight traffic and passenger traffic can be staggered. Several cities have earmarked late night hours for the movement of freight and restricted the entry of heavy trucks into cities during day time. Further, several cities have by-passes that enable through traffic to go around the city and not add to city traffic. Truck terminals have also been created in several cities on their peripheries and light commercial vehicles undertake the pickup and delivery services within the urban areas.

1.4 Universal Accessibility

Mobility is an integral part of our lives –we may need to go to school or work; see the doctor or meet friends; visit a restaurant, a gym or cinema; or simply fancy a walk or cycle ride. Universal accessibility is about making these trips continuous, convenient, safe and comfortable. The guiding principle of ‘universal accessibility’ is to create obstacle-free environments. It encompasses broad-spectrum ideas to create accessible streets, buildings and environment to the maximum extent possible. Accessibility here refers not only to persons with disabilities but to all possible users. It emphasizes inclusive environment in public spaces and infrastructure, accommodates the mobility needs of ‘all individuals’. All transit systems should provide universal accessibility.

The Constitution of India ensures equality, freedom, justice and dignity to all individuals and implicitly mandates an inclusive society for all including people with reduced mobility. It includes people with different abilities, senior citizens, women, and children, pregnant women, families with small children on prams, people carrying heavy luggage. Universal accessibility is an approach that covers everyone, so that transport services: (1) be used fairly; (2) provide high degree of freedom; (3) be simple and easy to understand; (4) be safe; (5) shall not require unnecessary bodily strength, and (6) maintain an appropriate space and size that is easy to use.

1.5 Smart Cities

The country has embarked upon a “Smart Cities” Mission. The objective is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of ‘Smart’ Solutions. The focus is on sustainable and inclusive development and the idea is to look at compact areas and create a replicable model for other aspiring cities.

The core infrastructure elements in a smart city include:

- Adequate water supply,
- Assure electricity supply,
- Sanitation, including solid waste management,

- Efficient and sustainable urban mobility,
- Affordable housing, especially for the poor,
- Robust IT connectivity and digitalization,
- Good governance, especially e-governance and citizen participation,
- Sustainable environment,
- Safety and security of citizens, particularly women, children and the elderly, and
- Health and education.

Accordingly, the Smart Cities Mission by enabling local area development and harnessing technology will lead to smart outcomes. Area based development will transform existing areas (retrofit and redevelop), including slums, into better planned ones, thereby improving liveability of the whole city. New areas (greenfield) will be developed around cities in order to accommodate the expanding population in urban areas. Application of Smart Solutions will enable cities to use technology, information and data to improve infrastructure and services (see **Fig. 1.3** as an illustration). Comprehensive development in this way will improve quality of life, create employment and enhance incomes for all, especially the poor and the disadvantaged, leading to inclusive cities.

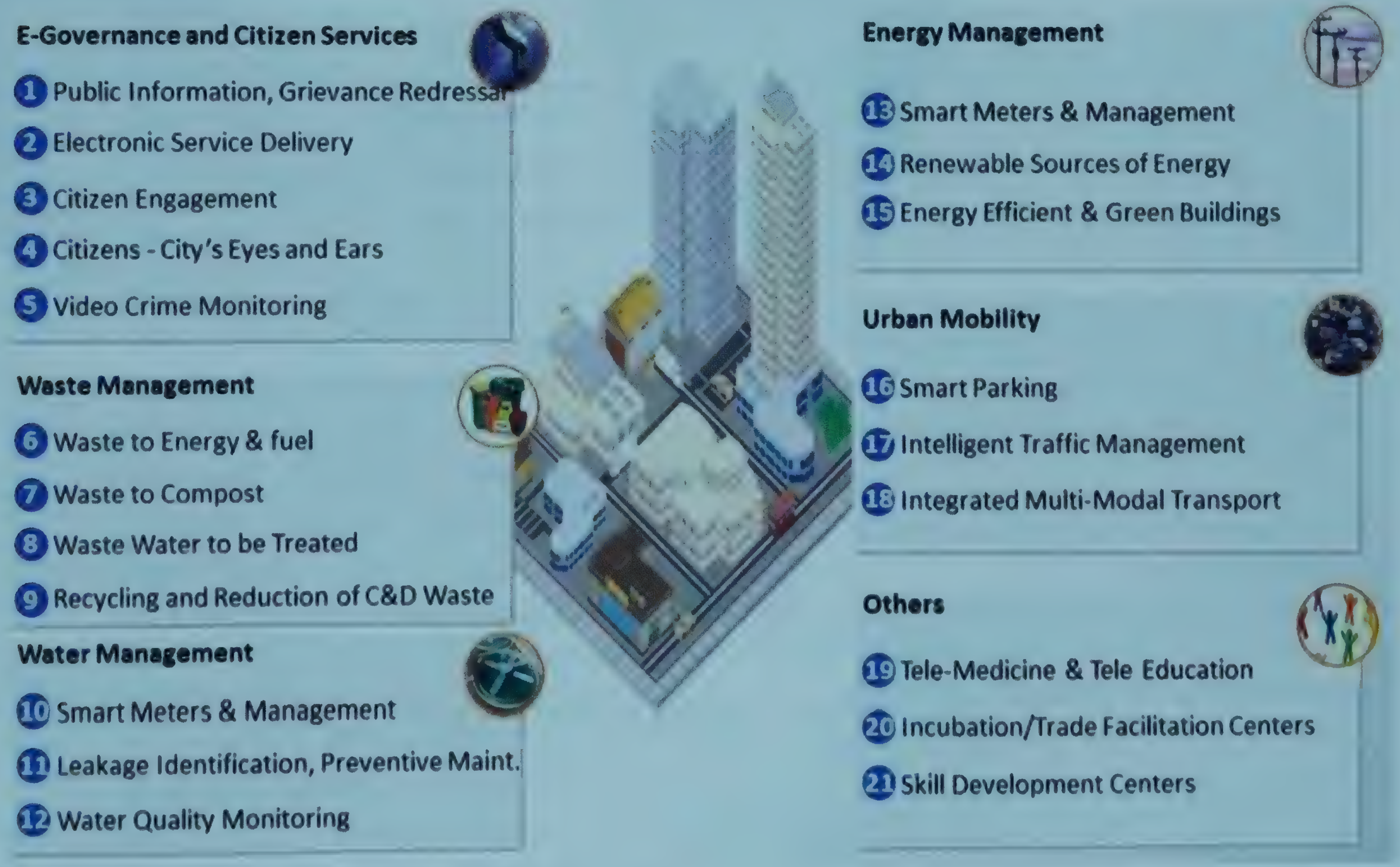

E-Governance and Citizen Services
1 Public Information, Grievance Redressal
2 Electronic Service Delivery
3 Citizen Engagement
4 Citizens - City's Eyes and Ears
5 Video Crime Monitoring
Waste Management
6 Waste to Energy & fuel
7 Waste to Compost
8 Waste Water to be Treated
9 Recycling and Reduction of C&D Waste
Water Management
10 Smart Meters & Management
11 Leakage Identification, Preventive Maint.
12 Water Quality Monitoring
Energy Management
13 Smart Meters & Management
14 Renewable Sources of Energy
15 Energy Efficient & Green Buildings
Urban Mobility
16 Smart Parking
17 Intelligent Traffic Management
18 Integrated Multi-Modal Transport
Others
19 Tele-Medicine & Tele Education
20 Incubation/Trade Facilitation Centers
21 Skill Development Centers

Fig. 1.3 Smart Solutions, Source: MoUD

1.6 Land Use and Transport Integration

Integrated spatial and transport planning in existing and new urban areas can reduce motorized travel by influencing the location, scale, density, design and mix of land uses, making it safer and easier for people to access jobs, shopping, leisure facilities and services by public transport, walking and cycling. Compact, dense and interconnected layouts are more suitable public transportation. Urban growth should be encouraged along mass rapid transit corridors to achieve transit-oriented development i.e. compact growth supported with mixed land uses, dense street networks, and mixed income housing. Consistent application of these planning policies will reduce reliance on private modes of transport and enable people to make sustainable transport choices. This will help in reducing congestion and air pollution.

1.6.1 *Mobility Planning*

Mobility planning in urban areas should give priority to the needs of pedestrians, cyclists and other non-motorized transport along with motorized vehicles. Focus should be given to mode priority indicated in **Fig. 1.4**. Planning should be done at two tiers: city-level and ward or local area plan levels, such that macro city level plans are duly supported with a second tier of detailed plans to facilitate walking and cycling within and across neighbourhoods, thereby providing sustainable, short distance and safe travel options.

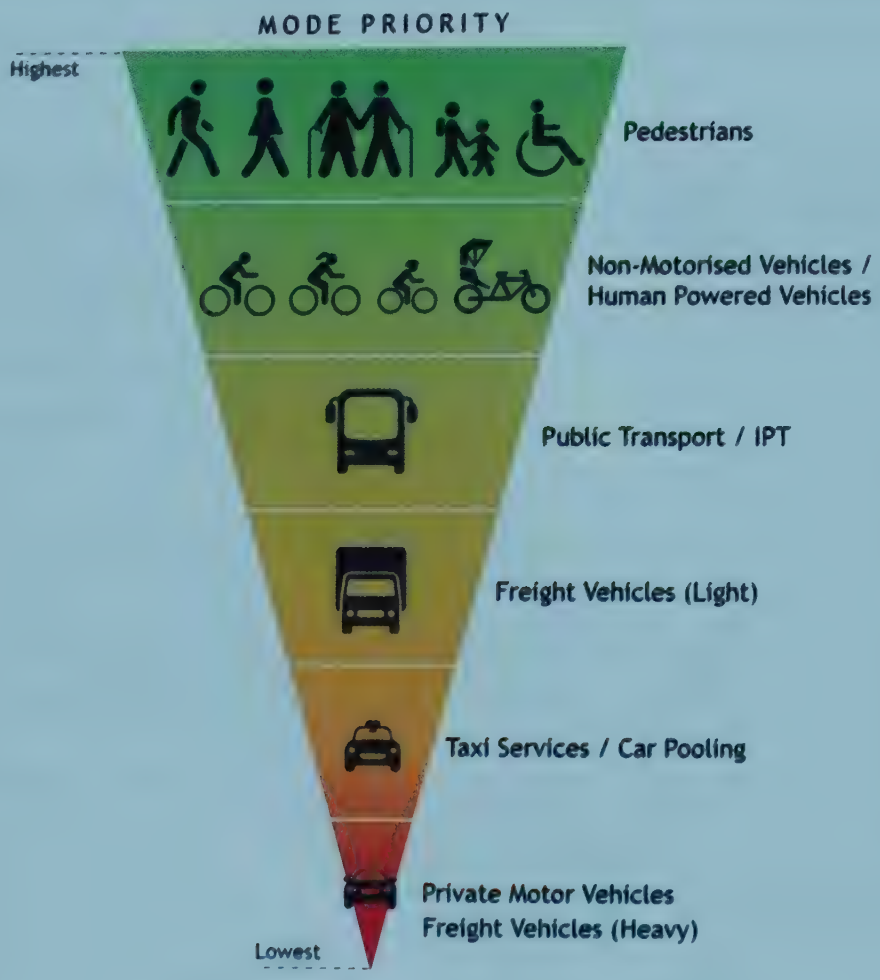

MODE PRIORITY
Highest
Pedestrians
Non-Motorised Vehicles / Human Powered Vehicles
Public Transport / IPT
Freight Vehicles (Light)
Taxi Services / Car Pooling
Private Motor Vehicles
Freight Vehicles (Heavy)
Lowest

Fig. 1.4 Mode Priority in Street Design

CHAPTER 2

PLANNING AND DEVELOPMENT OF URBAN ROADS AND STREETS

2.1 Introduction

This chapter draws heavily from IRC:SP:118 "Manual for Planning and Development of Urban Roads and Streets". It provides road network planning and street design guidelines for roads in new and existing urban areas. For more details and implementation process, the Manual may be referred. Mobility planning in urban areas should give priority to the needs of pedestrians, cyclists and non-motorized transport along with motorized vehicles. Planning should be done at both city-level and zonal, ward or local area plan levels.

2.2 Classification of Urban Roads and Streets

The following classes of urban roads and streets have been recommended in the IRC:SP:118-2018 "Manual for Planning and Development of Urban Roads and Streets".

- Urban Expressways
- Arterial Road
- Sub Arterial Road
- Collector Street
- Local Street
- Non-Motorized Transport (NMT) Streets and Greenways

2.2.1 *Definition*

- **Urban Expressway:** An urban expressway is defined as an urban arterial highway for high speed regional passenger and goods traffic from inter-city highways/expressways to connect to other inter-city highways entering the city at specific locations. These are full control access and having divided carriageways for high speed travel provided generally with grade separators at intersections.
- **Arterial Road:** A general term denoting a road/street primarily for through traffic, usually on a continuous route. Arterial roads facilitate mobility across the city and connect to long distance destinations within/outside the city while providing safe NMT facilities. On-street parking shall be prohibited or restricted, except when there is space available for a service lane with parking. Safety for pedestrians will be ensured by providing dedicated footpaths, at-grade pedestrian crossing with a median refuge.
- **Sub Arterial Road:** A general term denoting a road/street primarily for through traffic usually on a continuous route but offering somewhat lower level of traffic mobility than the arterial road. These are larger collector streets meant for movement through neighbourhoods and to connect to arterial roads.
- **Collector Street:** A street for collecting and distributing traffic from and to local streets and also for providing access to arterial/sub arterial roads. They shall be designed with dedicated footpaths. Various speed reduction measures will be employed to limit vehicle speeds to less than 40 kmph and ensure safety of NMT users.

- **Local Street:** A street primarily for access to residence, business or other abutting property. Its primary function shall be for local activities and access to properties and not through movement of traffic. Local street may not have a dedicated footpath and can be designed as shared space that gives priority to NMT modes. Various traffic calming elements will be employed to ensure that vehicle speeds are below 20 kmph, safe for intermingling of pedestrians, cyclists, and motor vehicles.
- **NMT Streets and Greenways:** All motor vehicle traffic will be prohibited, using barriers and enforcement of regulations to prevent their entry and encroachment of NMT space. Such streets will be designed in compliance with universal accessibility guidelines, with bicycle parking, and access for emergency response vehicles.

2.3 Design Principles, Objectives and Street Components

Urban Roads refer to the primary network comprising of arterial roads of a city-region and provide intra-city and regional connectivity through rapid transit, high frequency public transit and motor vehicle movement. These roads have provision of footpaths and may require physical segregation for non-motorized vehicles.

Urban Streets refer to the secondary network of the city comprising of 'sub-arterial, collector and local streets'. These connect neighbourhoods to the arterial road network and provide accessibility within neighbourhoods. This network is pedestrian and non-motorized vehicle focused with an emphasis on creating active public spaces.

2.3.1 *Design Principles*

- **Accessibility:** People of all age groups, gender and physical abilities should be able to move safely and seamlessly through the city.
- **Safety and Comfort:** Streets are safe, clean and walkable.
- **Ecology:** Streets are climate resilient and reduce impact on the natural environment.
- **Social Concerns:** Streets cater to the access needs of local communities.

2.3.2 *Design Objectives*

The design objectives of urban roads and streets are:

- Allocate the right of way equitably between motorized and non-motorized road users, catering to the needs of pedestrians, cyclists and public transport users.
- Create safe, traffic calmed environments.
- Provide climatic resilience and promote environmental sustainability.
- Create lively and vibrant public spaces.

2.3.3 *Street Components and Definitions*

- **Right of Way (RoW):** It is the space between two property lines, reserved for the movement of all transport modes (**Fig. 2.1**).
- **Cross section of the road:** It shows the space allocation for all motorized vehicles (cars, scooters, buses etc.), non-motorized vehicles (cycle, cycle rickshaws etc.), pedestrians, medians, street furniture, utilities, etc. within the Right of Way.

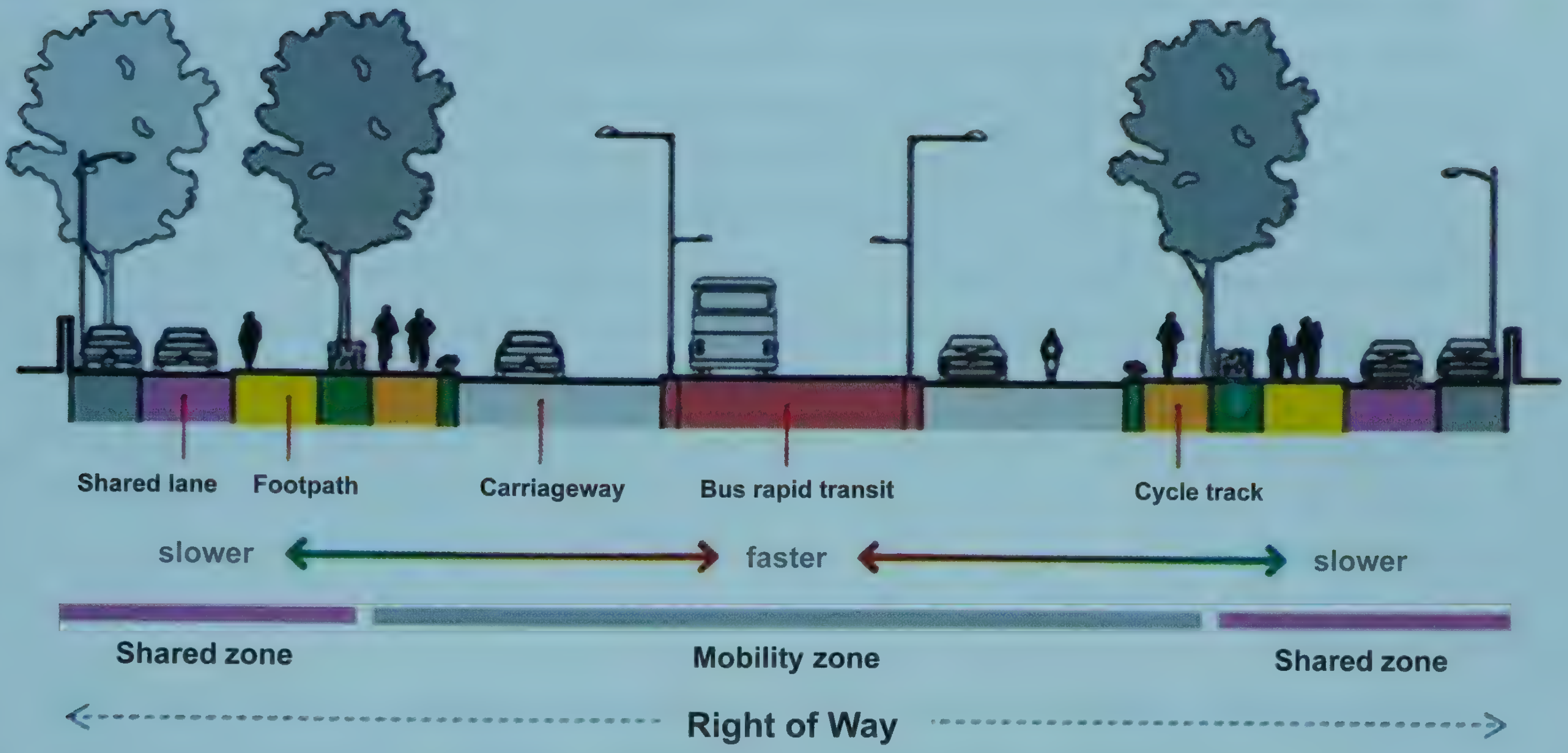


Fig. 2.1 Slow and Fast Zones of a Right of Way

Surface Space

- **Footpath:** It is a space reserved for movement of pedestrians and consists of a dead/ frontage zone, a pedestrian zone and a multi-functional zone for supporting amenities for pedestrians and other road users. For more details, see Chapter 5
- **Non-Motorized Vehicle Track:** It is a space reserved for movement of non-motorized vehicles like cycles, cycle rickshaws and hand pull carts.
- **Multi-Functional Zone:** A multi-functional zone ranges one to two metres wide. It is provided between the pedestrian zone and carriageway to provide amenities. It accommodates tree pits, storm water swales, auto-rickshaw stands, cycle-rickshaw stands, hawker zones, paid car parking, bus stops, traffic police booths, telecom boxes, fire hydrants, junction boxes, etc. street lights/pedestrian lights.
- **Bus Stops and Intermediate Public Transport (IPT) Stands:** This includes bus shelters and IPT shelters to provide sheltered waiting area for users.
- **Traffic Calming Measures:** Traffic calming slows down vehicles through vertical or horizontal displacement, real or perceived narrowing of carriageway, material/colour changes that signal conflict point, or complete closure of a street. These improve safety of both pedestrians and vehicle users.
- **Pedestrian Crossings:** These can be indicated through road markings or as table top crossings and facilitate crossing at mid-blocks and intersections.
- **Trees/Landscaping:** Trees provide shade. Planting can serve as water percolation pits, while improving the aesthetics of the street.
- **Street Lighting:** This encompasses lighting for the carriageway, footpaths and Non-Motorized Vehicle (NMV) tracks.
- **Street Vending:** Vendors provide affordable goods and services for all road users including pedestrians and cyclists. They are considered as a street element for Indian streets.

- **Signage:** This includes mandatory and regulatory, cautionary, direction and information traffic signages for pedestrians, cyclists, public transport and motor vehicle users.
- **Carriageway:** It is meant for movement of motorized vehicles and can be divided or undivided. Fair share of space within the RoW should be provided for pedestrians, cyclists and other NMT vehicles while planning for the carriageway width.
- **Service Lanes:** These are traffic calmed, shared streets provided at the edge of arterial roads to provide property access. They can increase the mobility function of the main carriageway while also maintaining liveability for non-motorized road users.
- **On-street Parking:** The space occupied by vehicles to park along the edge of the street or carriageway which otherwise could have been used by motorized or non-motorized traffic.

Underground Space

- **Urban Street Utilities:** All city level underground sewers, water, electric and other communication cable lines should be properly mapped and re-laid wherever feasible in underground service ducts or Hume pipes. Careful location and planning of urban utilities is critical –to allow easy access for regular repair and maintenance of utilities, while causing minimum disruption to other street users. Proper focus on storm water drainage system planning and management is needed. For more details, refer IRC:98.
- **Common Utility Ducts/Duct Bank:** Common ducts may be provided for city level utilities (such as sewers, water supply, electricity etc.) and separately for street utilities (such as local storm water drains, information technology, telecom, street lighting cables, etc.) during the laying/relaying/retrofitting of roads. For more details, refer IRC:98.

2.4 Space Standards

The space standards recommended for the various categories of urban roads are given in **Table 2.1**. The term” space standard” is often referred to as “right-of-way”.

Table 2.1 Recommended Land Widths for Roads in Urban Areas

Sl. No.	Class of Road/Street	Right of Way Width (meters) and Type of Terrain		
		Plain	Rolling	Hilly
1	Urban Expressway	45-60	35-50	30-40
2	Arterial Road	45-60	35-50	25-40
3	Sub Arterial Road	30-45	25-35	20-30
4	Collector Road	15-30	12-25	12-20
5	Local Street	10-15	10-15	10-15

2.5 Functions and Planning Considerations

The functions and planning considerations for new roads and redesign of existing roads are given in **Tables 2.2** and **2.3**.

Table 2.2 Functions and Planning Considerations for Urban Roads and Streets in New Areas

	Urban Expressways and Bypass Roads	Arterial Roads	Sub Arterial Roads	Collector Streets	Local Streets	Non-Motorized Transport Pathways and Greenways
Functions	☐ Caters to long distance regional passenger and goods traffic either bypassing the city or destined to selected parts of the city.	☐ Primary network of a city. ☐ Provide intra-city long distance travel by multi-modal transportation system connecting all major city level land uses. ☐ Facilitate intercity/ regional trips by connecting with the highway and expressway network.	☐ Secondary network of the city connecting multiple neighbourhoods to the arterial roads.	☐ Supplements the secondary street network system by improving accessibility within and across neighbourhoods.	☐ Network providing non-motorized travel opportunity within the neighbourhood and access to motorized traffic as last mile connectivity.	☐ Streets catering only to pedestrians and non-motorized transport (including cycles and cycle rickshaws, cycle carts).
Planning Considerations for New Urban Roads and Streets ☐ Streets shall be designed as Complete Streets as described in Sections 2.3.1 and 2.3.2	☐ Uninterrupted vehicular movement with traffic interchanges with highway and arterial roads. ☐ Access to properties shall be facilitated through service roads. ☐ Bypasses should be decided by the City/Municipal / Development Authorities, in consultation with the road agency.	☐ Network of 1000m x 1000m. The right of way shall allocate space for future provision of a mass rapid transit system. ☐ Dedicated space for footpaths as per IRC:103 and non-motorized vehicle tracks to create a safe network for pedestrians and cyclists.	☐ Network of 500m x 500m. ☐ The right of way shall allocate space for future provision of a mass rapid transit system. ☐ Dedicated space for footpaths as per IRC:103 and non-motorized vehicle tracks to create a safe network for pedestrians and cyclists.	☐ Network of 250m x 250m. ☐ 24-30m right of way: Divided carriageway with a maximum of 2 lanes per direction, pedestrian facilities as per IRC:103 and cycle tracks. ☐ Median shall be intermittent to allow for connectivity to local streets and U-turns.	☐ Network of 125m x 125m. ☐ Dedicated footpaths as per IRC:103. ☐ Streets with right of way less than 12m may be considered in consultation with the road department. These can be traffic calmed shared space with priority to non-motorized transport.	☐ Spacing should not be >125m. ☐ No restrictions on pedestrian and non-motorized vehicle access from adjoining properties. ☐ Compound walls shall not be higher than 1m ☐ Motorized vehicles and their parking are not permitted.

	Urban Expressways and Bypass Roads	Arterial Roads	Sub Arterial Roads	Collector Streets	Local Streets	Non-Motorized Transport Pathways and Greenways
	☐ Interchanges may be provided at highway-highway junctions.	☐ Pedestrian crossings at intersections and mid-blocks as per IRC:103. ☐ Carriageway with maximum 3 lanes per direction. ☐ On-street parking is not permitted. ☐ Access to properties may be facilitated by service roads. ☐ Interchanges are only permitted with expressways in peri-urban areas.	☐ Pedestrian crossings at intersections and mid-blocks as per IRC:103. ☐ Carriageway with maximum 2 lanes per direction. Parallel motorized vehicle parking after providing footpaths as per IRC:103 and non-motorized vehicle tracks. ☐ Parking to be accommodated in the multi-functional zone. ☐ Interchanges are prohibited.	☐ <24m Right of Way: Undivided carriageway with one lane per direction and pedestrian facilities as per IRC:103. ☐ Combined cycle track may be considered for roads with ROW varying between 18m and 24m. ☐ On-street parallel motor vehicle parking after providing pedestrian and non-motorized vehicle facilities. ☐ Parking to be accommodated in the multi-functional zone. ☐ No flyover/ elevated roads and interchanges on this class		☐ Designated parking for non-motorized vehicles to be provided.

Table 2.3 Planning Considerations for Existing Urban Roads and Streets

	Urban Expressways and Bypass Roads	Arterial Roads	Sub Arterial Roads	Collector Streets	Local Streets	Non-Motorized Transport Pathways and Greenways
Planning Considerations for Existing Urban Roads and Streets ☐ Existing streets shall be designed as Complete Streets. (Refer Sections 2.3.1 and 2.3.2)	☐ Since existing streets have an uneven right of way, the carriageway shall be consistent considering the minimum right of way of the road.					
	☐ Expressways passing through the city/urban area shall be designed for uninterrupted vehicular movement with traffic interchanges with highway and arterial roads.	☐ The RoW of numerous arterial roads in Indian cities is less than 45m. The classification shall be based on its function and not on the right of way. ☐ Dedicated space for footpaths and non-motorized vehicle tracks to create a safe network for pedestrians and cyclists. ☐ Pedestrian crossings at intersections and mid-blocks as per IRC:103. ☐ Divided carriageway with maximum 3 lanes per direction. ☐ On-street parking is not permitted.	☐ Dedicated space for footpaths and non-motorized vehicle tracks to create a safe network for pedestrians and cyclists. ☐ Pedestrian crossings at intersections and mid-blocks as per IRC:103. ☐ Divided carriageway with maximum 2 lanes per direction. ☐ Parking management shall be introduced. ☐ Parallel motorized vehicle parking after providing pedestrian and non-motorized vehicle facilities. ☐ Parking to be accommodated in the multi-functional zone.	☐ Collector streets with 24m and above right of way, divided carriageway with a maximum of 2 lanes per direction, pedestrian facilities as per IRC:103 and cycle tracks. ☐ The median shall be intermittent to allow for connectivity to local streets and U-turns. ☐ Collector streets with right of way less than 24m may have an undivided carriageway with maximum one lane per direction and pedestrian facilities as per IRC:103. ☐ Combined cycle track may be considered for collector streets varying between 18-24m.	☐ Streets with right of way greater than 12m shall provide dedicated footpaths and pedestrian crossings as per IRC:103. ☐ Streets with right of way less than 12m may be traffic calmed shared space with priority to non-motorized transport modes. ☐ Some local streets in the neighbourhood should be developed as car free streets i.e. only for walking/cycling for enhanced community life.	☐ Can be created by combining side or rear open spaces of buildings. ☐ No restrictions on pedestrian and NMV access from adjoining properties. ☐ Compound walls shall not be higher than 1m ☐ Motorized vehicles and their parking are not permitted. ☐ Designated parking for non-motorized vehicles to be provided.

	Urban Expressways and Bypass Roads	Arterial Roads	Sub Arterial Roads	Collector Streets	Local Streets	Non-Motorized Transport Pathways and Greenways
		☐ The road capacity shall be augmented to promote public transport i.e. increasing passenger capacity by providing mass rapid transit and/ or upgrading public transport systems, and non-motorized transport. Before flyovers, and elevated corridor proposals are taken up, an alternative analysis of capacity augmentation through public transport, pedestrian and non-motorized transport improvements shall be conducted. ☐ Additionally, a quantitative comparison of the environmental, economic and social benefits	☐ Interchanges are prohibited. ☐ Road capacity shall be augmented based on increasing passenger capacity by providing and/ or upgrading public transport systems and promoting non-motorized transport. Before flyovers, and elevated corridor proposals are taken up, an alternative analysis of capacity augmentation through public transport, pedestrian and non-motorized transport improvements shall be conducted. ☐ Construction of any flyover/ elevated roads after above	☐ Motorized on-street parking may be permitted. ☐ On-street parking management to be introduced. ☐ Parallel motorized vehicle parking after providing pedestrian and NMV facilities ☐ Parking to be accommodated in the multi-functional zone. ☐ No flyover/ elevated roads, interchanges on this class.		

	Urban Expressways and Bypass Roads	Arterial Roads	Sub Arterial Roads	Collector Streets	Local Streets	Non-Motorized Transport Pathways and Greenways
		and cost of both proposals shall be conducted. ☐ Construction of any flyover/ elevated roads on arterial roads after above consideration should be accommodated within the carriageway without encroaching / affecting any space already developed or reserved for pedestrians and non-motorized vehicles and other street elements. Pedestrian foot over bridges and subways may be discouraged. Service roads may be re-designed to facilitate movement of pedestrians and other local traffic.	consideration should be accommodated within the carriageway without encroaching on or affecting any space already developed or reserved for pedestrians, non-motorized vehicles and other street elements.			

2.6 Transport Network Planning

2.6.1 *Network Planning Principles*

The urban roads and street network shall:

- Accommodate the travel demand of all road users with provision of space for all modes satisfying the safety, equality and environment criteria.
- Provide an efficient and safe movement of non-motorized traffic and pedestrians along with motorized traffic.
- Achieve universal accessibility with the specific provisions for people with disability/ restricted mobility, elderly, women and children.
- Develop a complete road system to distribute traffic over the entire network.
- Develop a secondary network for short distance (localised) non-motorized travel and integrate it with the arterial network for long distance travel.
- Suburban road network planning with low density, gated communities serviced by high speed corridors and cul-de sacs shall be avoided. These increase walking and cycling distances and do not facilitate planning for public transit.

2.6.2 *Urban Road Network Pattern*

Urban road network density, which determines block sizes are a key indicator of auto-centric or walkable neighbourhoods and cities. In the absence of well developed secondary and local street networks, even the local traffic tends to accumulate at a few major junctions, causing large queue lengths and congestion at these locations, while majority of the internal streets might remain under-utilized due to discontinuity. A lack of these networks also forces pedestrians and NMT to take long detours even for short distances

2.6.3 *Existing Urban Road Network and Retrofitting*

The urban road network currently favours motor vehicles. Around 70-80 percent of the road space is occupied by the 20-30 percent of people using private motor vehicles. The retrofitting of existing roads should accommodate space for all users - pedestrians, non-motorized vehicles, public transport modes/buses, and motor vehicles. More details refer IRC:SP:118.

2.6.4 *Urban Road Network for Greenfield Development*

The urban planning approach needs a paradigm shift to a grid street network with dense, mixed use development to reduce travel lengths and auto dependency in cities. The close grid network will help uniform distribution of motorized traffic and avoid congestion at critical points on arterial roads and neighbourhood roads simultaneously. This will also increase mobility space for all non-motorized modes. Whereas long distance travel can be catered by high speed, high capacity transit and motorized traffic on arterial network, the short/medium distance travel can largely be catered by a combination of para-transit and non-motorized modes on the secondary street network system. About 25-30 percent of land space should generally be reserved in the Master Plan/Development Plan for all categories of roads. For details, refer IRC:SP:118 "Manual for Planning and Development of Urban Roads and Streets".

2.7 Principles of a Pedestrian Network

- **Segregation:** Physical segregation of pedestrians from the vehicles on the road can enhance safety in urban areas. Importance of segregation should not be limited to providing only footpaths along the road but should also include safe crossings on streets at strategic locations with various traffic control measures like traffic signals, road signages and markings. For more details, see chapter 5 and IRC:103 and IRC:86.
- **Active Streets:** Streets where building edges/frontages are oriented toward and directly accessible from the street on foot to promote pedestrian activity. Two major aspects to be considered to transform a city street into an active street.
    - Create "eyes on the street" – by removing setbacks and boundary walls and building to the edge of the street right of way. This would allow people from inside to look out on to the pavement, thus enhancing women and girls' safety and discouraging criminal activities, misbehaviour, shady corners, etc.
    - Create commercial/hawking zones at regular intervals to encourage walkability, increase street activity and enhance safety.
- **Pedestrianized Streets/Plazas/Squares:** Car free pedestrian streets and plazas may be considered for retail streets, market streets, and feeder streets to mass transit stations or inner-city areas (Some examples include the pedestrian mall roads in Shillong and Gangtok).

2.8 Principles of a Non-Motorized Vehicle Network

Non-motorized vehicles offer low-cost, pollution-free mobility. Cycles occupy only one-fifth as much driving and parking space as automobiles. Due to the lack of physical separation from motorized vehicles, non-motorized vehicles face inconvenience and safety hazards from faster moving traffic. Where motor vehicle lanes are saturated, cycling in a segregated track is often faster and safer. Good cycle tracks are continuous and provide for uninterrupted movement. For more details refer IRC:86, IRC:SP:118 and IRC:11.

2.9 Principles of a Public Transport Network

- **Integrated Road and Transit Network System:** A road network system defines the public transport accessibility level such that people can access it within 500m walking distance. The arterial corridors provide for high capacity multi modal transit system and physical integration through interchange facilities. The bus stands/terminals, bus stops with adequate space provisions with amenities for passengers are critical requirements and need to be incorporated in secondary road network plans. For more details, see IRC:86.

2.10 Multi-modal Integration

Multimodal transportation system is the integration of various modes of travel – bus rapid transit, city bus, metro, light rail transit, monorail, walking and cycling for improved and efficient service. Particularly, in the vicinity of 500m of mass transit stations, multi-modal integration includes

- Minimize the time required for mode transfers for maximum commuters.
- Prioritizing safe pedestrian and cycling access to mass rapid transit.

- Providing seamless integration with feeder modes and intermediate public transport services.
- Introducing on-street parking management.
- Creating an enhanced public realm for people.

2.11 Principles for Intersections, Interchanges and Traffic Rotaries

One of the major challenges in creating, well-connected networks is the design and planning of junctions along major arterial roads. For design guidelines and standards of intersections and interchanges, refer IRC:SP:41 and IRC:92 respectively.

2.12 Principles of Parking Management

The use of personal motor vehicles shall be effectively managed by implementing a formal parking management program. Footpaths, cycle tracks, and other non-motorized transport facilities will be designated as no-parking zones.

2.13 Principles of Street Vending Management

Street vending shall be managed in accordance with the provisions of the National Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act, 2014 and relevant state rules. Street vending shall be regulated to ensure the continuity of footpaths and cycle tracks.

2.14 Access Management

2.14.1 *Access Management Principles*

The following principles may apply for access management on roads and streets in urban areas:

- Where service roads are provided, urban arterial roads should not have a direct vehicular access to any plots or building from the road.
- Larger plots with off-street parking facilities should be accessed from the side road. For smaller plots, parking should be unbundled and provided at strategic parking plots.
- All plots shall have pedestrian and cycle access directly from footpath and cycle track along arterial roads.

2.14.2 *Service Roads*

Service roads improve safety and throughput by segregating property access points and parking from the main carriageway. They can increase the mobility function of the main carriageway while also maintaining liveability and smooth travel for non-motorized road users. With reduced speeds because of traffic calming, service roads can function as slow shared spaces. Service roads should not be continuous and should be interrupted by pedestrian bulb-outs at regular intervals to discourage fast driving and provide safe property access, and render safe environment for pedestrians and non-motorized vehicles. Loading and unloading of goods and on-street parking may be accommodated within the multi-functional zone of the footpaths. Access into and out of a service road should be provided via a ramped crossing over the footpath and cycle track, which continue at original levels. For more details, refer IRC:SP:87.

2.15 Street Design and Implementation Process

The street design process for existing roads is shown in **Fig. 2.2**. It describes the process for identifying a road stretch for improvement, surveys and analyses to be conducted, preparation of a concept plan and testing on site, preparation of a complete street tender and construction and supervision. For details, refer to IRC:SP:118 "Manual for Planning and Development of Urban Roads and Streets".

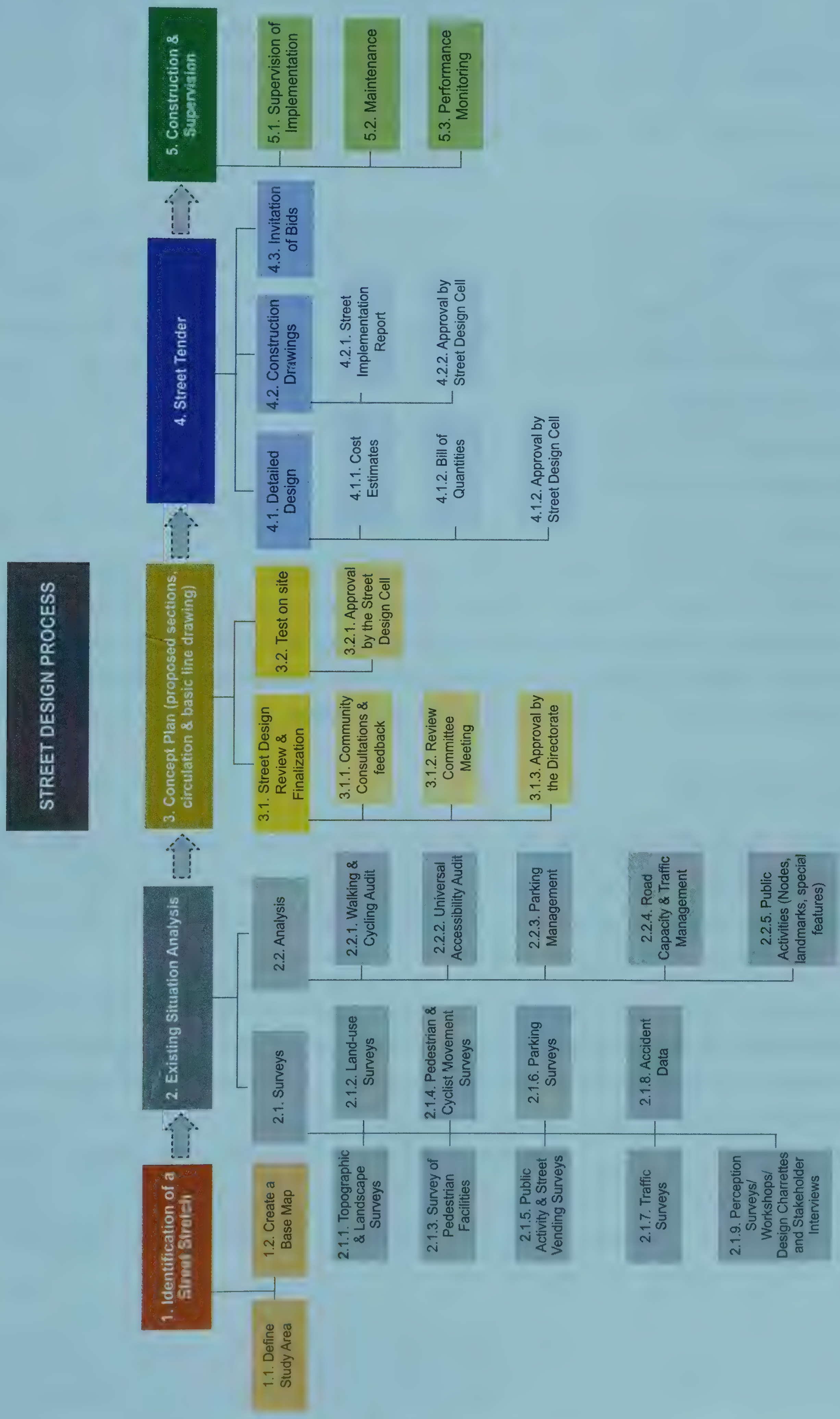

STREET DESIGN PROCESS
1. Identification of a Street Stretch
1.1. Define Study Area
1.2. Create a Base Map
2. Existing Situation Analysis
2.1. Surveys
2.1.1. Topographic & Landscape Surveys
2.1.2. Land-use Surveys
2.1.3. Survey of Pedestrian Facilities
2.1.4. Pedestrian & Cyclist Movement Surveys
2.1.5. Public Activity & Street Vending Surveys
2.1.6. Parking Surveys
2.1.7. Traffic Surveys
2.1.8. Accident Data
2.1.9. Perception Surveys/ Workshops/ Design Charrettes and Stakeholder Interviews
2.2. Analysis
2.2.1. Walking & Cycling Audit
2.2.2. Universal Accessibility Audit
2.2.3. Parking Management
2.2.4. Road Capacity & Traffic Management
2.2.5. Public Activities (Nodes, landmarks, special features)
3. Concept Plan (proposed sections, circulation & basic line drawing)
3.1. Street Design Review & Finalization
3.1.1. Community Consultations & feedback
3.1.2. Review Committee Meeting
3.1.3. Approval by the Directorate
3.2. Test on site
3.2.1. Approval by the Street Design Cell
4. Street Tender
4.1. Detailed Design
4.1.1. Cost Estimates
4.1.2. Bill of Quantities
4.1.2. Approval by Street Design Cell
4.2. Construction Drawings
4.2.1. Street Implementation Report
4.2.2. Approval by Street Design Cell
4.3. Invitation of Bids
5. Construction & Supervision
5.1. Supervision of Implementation
5.2. Maintenance
5.3. Performance Monitoring

Fig. 2.2 Design and Implementation Process for Existing Street

CHAPTER 3

GEOMETRIC DESIGN STANDARDS

3.1 Introduction

Geometric design is influenced by a number of factors such as modal shares, nature of terrain, type, composition and volume of traffic, design speed, and land use characteristics, integrating factors (mobility, safety and ecology). This chapter draws heavily from the IRC publication - IRC:86 "Geometric Design Standards for Urban Roads and Streets".

Geometric design includes the following elements.

- Design speeds
- Horizontal Alignment
- Vertical Alignment
- Cross Sectional Elements
- Intersections and Interchanges
- Essential Components
    - Pedestrian Side Walks and Crossings
    - Non Motorized Traffic (NMT)
    - Inclusive facility for persons with disability, elderly.

3.2 Design Controls

The design of road should be safe, efficient, functional and economical for pedestrians, non motorised vehicles and motorized vehicular traffic. The design controls are human factors, road space allocation, speeds, design vehicles and sight distances.

Definitions of Various Speeds

Speed is an important element in geometric design. The factors influencing speeds are driver characteristics, vehicular characteristics, road characteristics, traffic composition, weather and speed limits. Design speed and posted speed are key instruments, which can be used to regulate the speed of motor vehicles through road design and enforcement.

- **Design speed:** The speed selected as a safe basis to establish appropriate geometric design elements for particular sections of road. It should be a logical one with respect to topography, anticipated operating speed, the adjacent land use and functional classification of road.
- **Posted Speed:** Is a speed limitation set for reason of safe traffic operations on a particular stretch of road keeping in view the prevailing geometric condition and land use characteristics. Selection of posted speed is an operational decision.

Design Speed

Keeping in view type of function expected of each class of the urban road system, the design speeds (km/h) are given in **Table 3.1**. The design speed should preferably be uniform along the given road/street. The design speeds for both mountainous and steep terrain may be the same.

Table 3.1 Design Speeds (km/h)

Sl. No	Class of Urban Road	Type of Terrain		
		Plain	Rolling	Mountainous and steep
1	Urban Expressway	80	70	60
2	Arterial Road	60	50	40
3	Sub Arterial Road	60	50	40
4	Collector Street	40	40	30
5	Local Street	30	30	20

Posted Speed

While design speeds should be uniform over a road stretch, a lower value compared to that designated in **Table 3.1** may be adopted for posted speeds depending on the presence of physical controls, roadside development and related factors. For example, a posted speed of 20 kmph in the vicinity of schools, colleges, universities, hospitals, 500m around mass transit stations, dense urban cores and central business districts. The sudden change in posted speeds along a stretch of road should be avoided. Change should be made in stages in steps of 10 km/h at a time.

3.3 Cross-Sectional Elements

The width and layout of urban road cross-section depend on many factors, the chief amongst them being the classification of road, design speed, and the volume of traffic expected. Other considerations are requirements of parking lanes, bus-bays, loading-unloading bays, occurrence of access points, volume of pedestrians and cyclists, width of drains, location of sewer lines, electricity cables and other public utility services.

3.3.1 *Footpath (Sidewalk)*

Footpaths are defined as any area primarily used by 'all' pedestrians. They can be adjacent to roadways or away from the road. A footpath should consist of a dead or frontage zone, pedestrian zone and a multi-functional zone. For details, refer Chapter 5.

3.3.2 *Non-Motorized Vehicle Tracks*

Non-Motorized Vehicles (NMV) includes cycles, tri-cycles, cycle rickshaws, pushcarts, and any other form of mobility that is powered by humans. NMV plays an important role in efficient transport system. Urban local bodies should create city-wide NMV network plans to ensure that streets are safe for cycling. For details, refer Chapter 6.

3.3.3 *Road Width and Design Traffic Volumes*

The road width should be designed to accommodate the design traffic volume. Past traffic counts and consideration of future development of urban areas must be kept in view while selecting the cross-section of road. The road should be designed to accommodate the traffic volumes computed for the end of design life. A design period of 15-20 years should be adopted for expressways and arterials and 10 years for local and collector streets. For broad assessment, the peak hour flows may be taken as 8-10 per cent of the average daily traffic.

Urban roads in India are characterised by mixed traffic conditions, resulting in complex interaction between various kinds of vehicles. To cater to this, it is prudent to express the capacity of urban roads in terms of a common unit. The unit generally employed is the 'Passenger Car Unit, (PCU) and each vehicle type is converted into equivalent PCUs based on their relative size and speed.

3.3.4 *Carriageway Width*

The primary purpose of a carriageway is vehicle mobility. A carriageway provides dedicated space for motorised vehicles separated from walking, cycling, and stationary activities. Carriageways are located in the middle of the street right-of-way. Street designs should define clear boundaries through kerbs and material differences. One-way carriageways should be reviewed and provided if necessary to accommodate rapid transit (such as BRT) corridors or pedestrian zones. Where one-way streets are proposed, two-way movement for NMT modes may be considered. **Table 3.2** gives the recommended carriageway width.

Table 3.2 Recommended Carriageway Widths

Description	**Width (m)**
Single Lane without Kerbs	3.5
Two Lane without kerbs	7.00
2- lane with kerbs	7.50
4- lane without kerbs	(7.00 x 2) 14.0
6- lane without kerbs	(10.5 x 2) 21.0

3.3.5 *Kerb and Kerb Ramp*

It is desirable that roads in urban areas are provided with kerbs. Kerbs may be barrier type, semi-barrier type or mountable type. Appropriate situations for use of each type are indicated below:

- Barrier type: Built-up areas adjacent to footpaths with considerable pedestrian traffic.
- Semi-barrier type: On the periphery of the roadway where pedestrian traffic is light and a barrier type could tend to reduce traffic capacity.
- Mountable type: Within the roadway at channelization schemes, medians, outer separators and raised medians on bridges.

3.3.6 *Medians*

Urban roads of four lanes or more should, as a general rule, be provided with median. For four-lane roads, however, the provision of median should be judicious taking into account such considerations as safety, directional distribution of traffic, proportion of slow-moving traffic, roadside development and quality of service, etc. Medians could be avoided where there are significant tidal flows of traffic, or where the individual carriageways are inadequate for catering to peak-hour traffic volumes, or where there are intense roadside developments without frontage roads. Width of median is dictated by a variety of conditions. Width will depend on the available right-of-way, terrain, turn lanes, drainage and other determinants. Minimum width of median at intersection to accomplish various purposes should be as follows: (i) Pedestrian refuge, 1.2 m; (ii) Median lane for protection of vehicle making right turn, 4.0 m but 7.5 m is recommended; (iii) 9 to 12 metre is required to protect vehicles crossing at grade. Even greater widths are required for U-turns. Absolute minimum width of median in urban areas is 1.2 m; a desirable minimum width is 5 m. As far as possible, the median should be of uniform width in a particular section. However, where changes are unavoidable, a transition of 1 in 15 to 1 in 20 must be provided.

3.3.7 *Verge*

Verges are required between carriageway and property line not only to accommodate lighting columns, traffic signs, underground services etc., but also to provide appropriate clearance to ensure proper vehicle placement and development of full carriageway capacity. Where road width is restricted, full width between carriageway and property line should be paved and used for pedestrian side walk/cycle track. Where possible, a minimum verge of 1 m width should be kept. They should be suitably levelled, trimmed and provided with a cross fall of 5 per cent if turfed and 3 per cent if cobbled or surface dressed. This should be increased if poles, kerb-height, or excessive cross fall discourage parking close to the kerb and also where either parked vehicles frequently overlap on to the adjacent traffic lane or the parking lane is likely to be used as a peak hour traffic lane.

3.3.8 *Street Lighting*

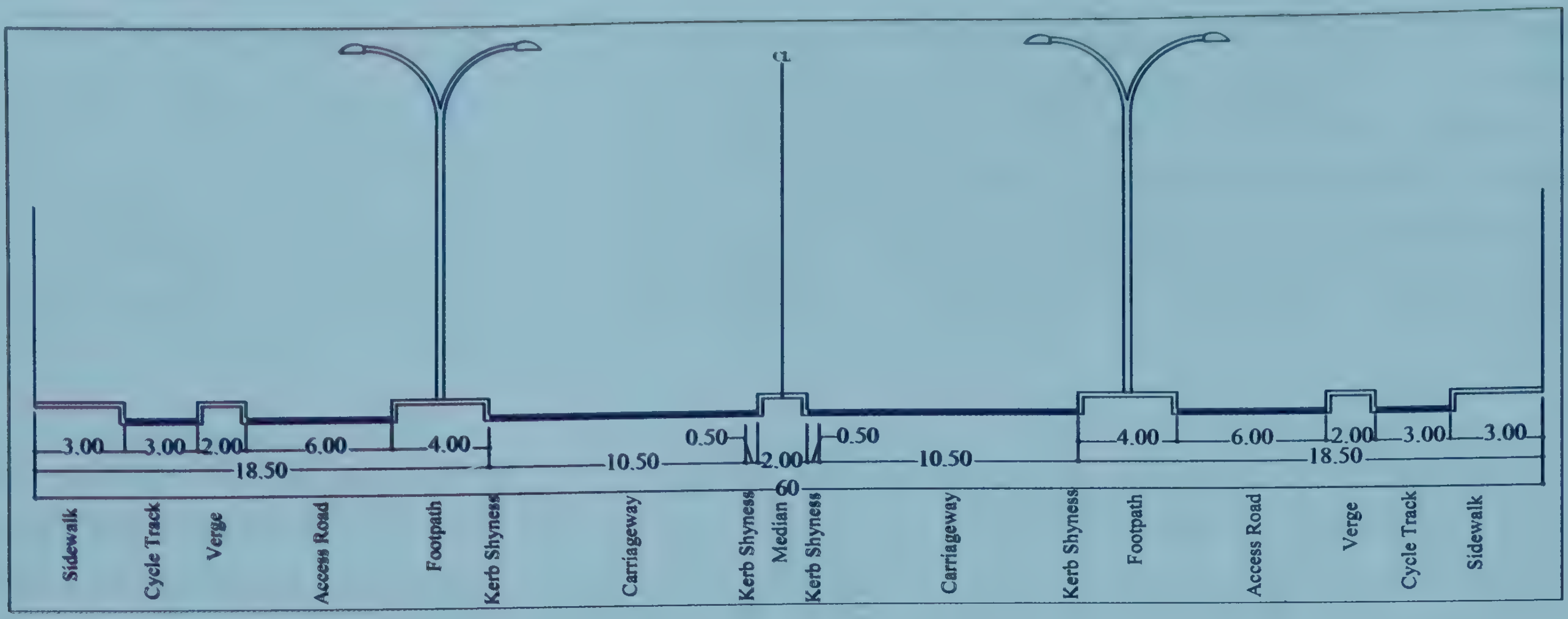
Street lighting shall be provided such that the longitudinal dimension is equivalent to three times the pole height, and horizontal dimension is slightly longer than the pole. For details, refer to Chapter on Lighting.

3.3.9 *Typical Cross Sections*

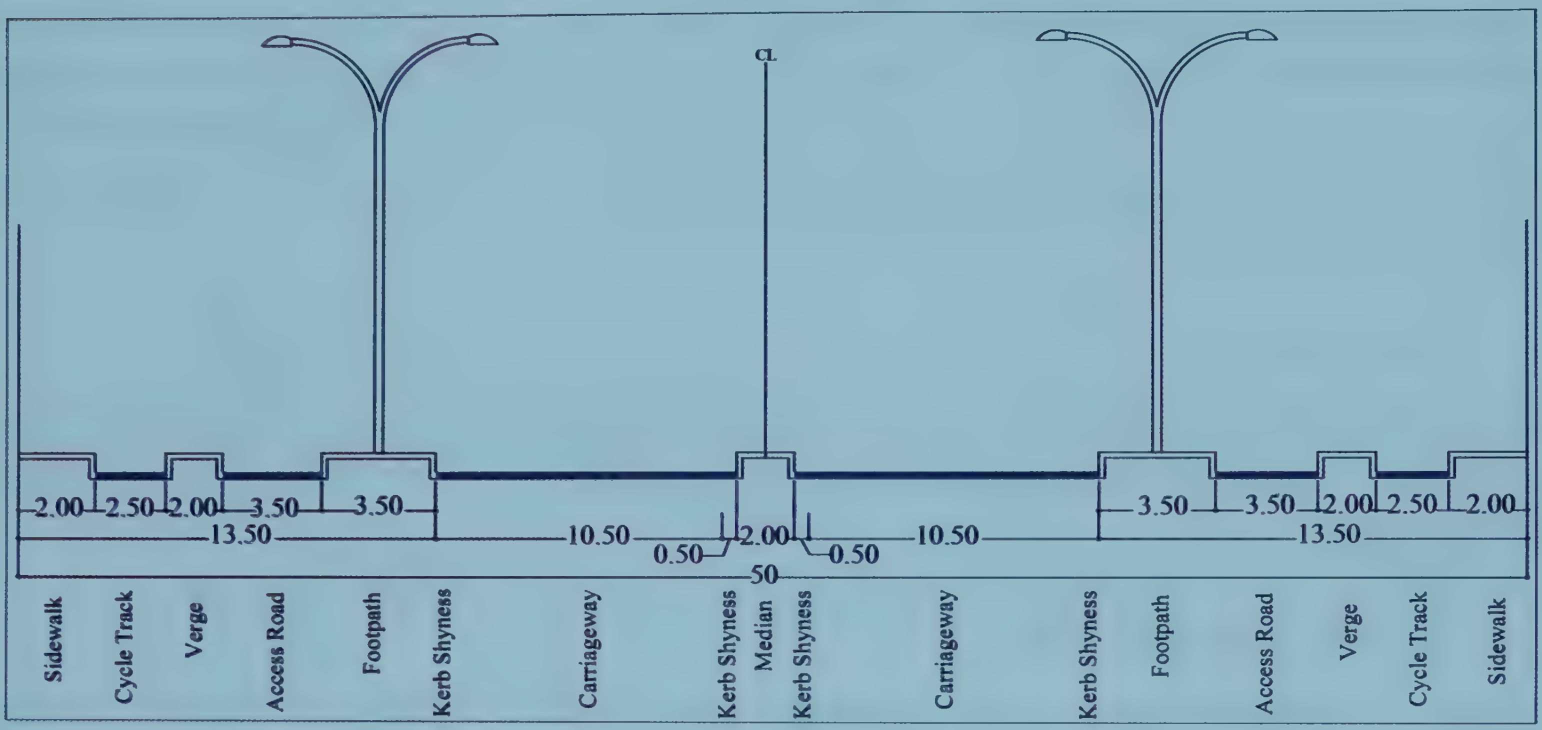
Typical cross-sections of various categories of urban roads and streets are given in **Figs. 3.1** to **3.5** for various terrains as below:

- **Fig. 3.1** shows typical cross section of Arterial Roads in plain, rolling and hilly terrain
- **Fig. 3.2** shows typical cross section of Sub-Arterial roads in plain, rolling and hilly terrain
- **Fig. 3.3** shows typical cross section of Collector Streets in plain, rolling and hilly terrain
- **Fig. 3.4** shows typical cross section of Local Streets in plain, rolling and hilly terrain
- **Fig. 3.5** shows typical cross section of Urban Expressways in plain, rolling and hilly terrain.

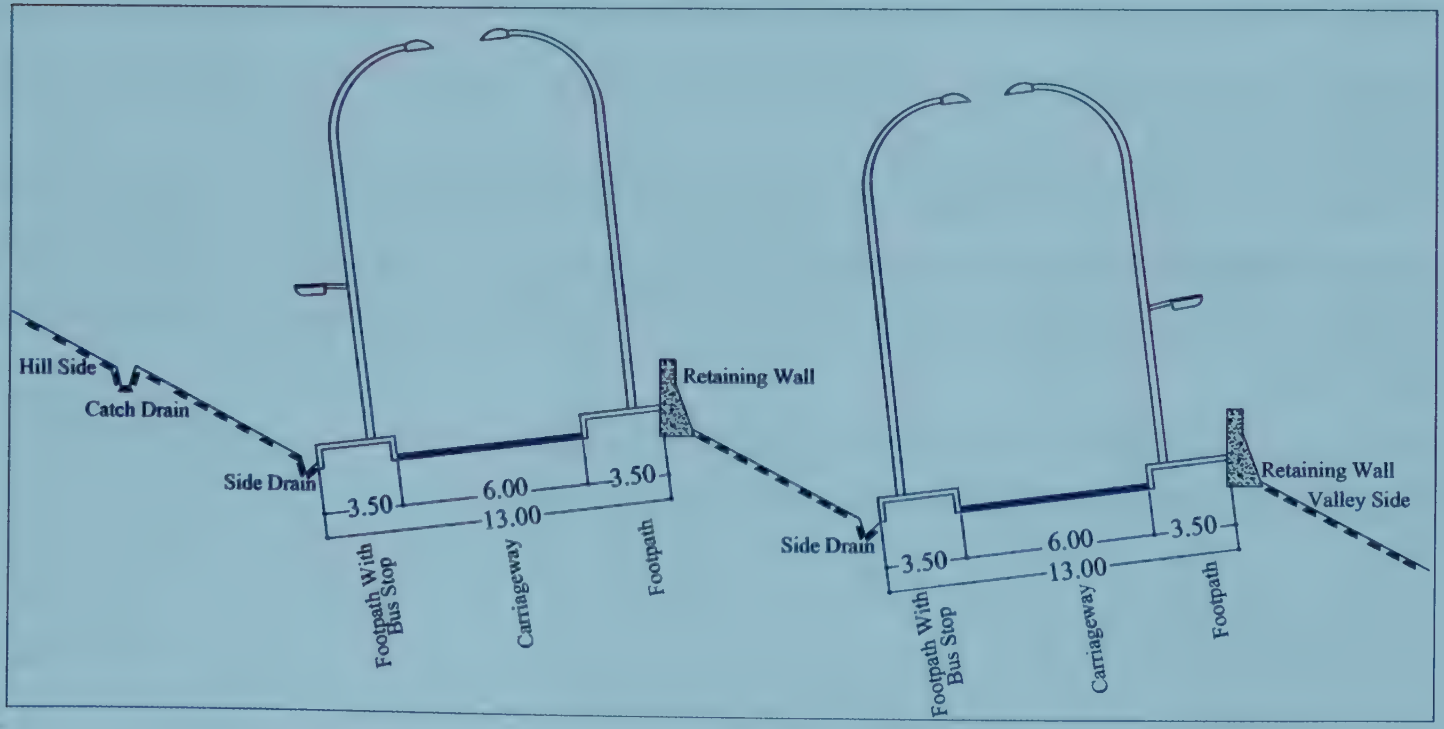
Actual width of each element should be decided based on traffic volume, pedestrian and non motorised traffic volume and other functional requirements.


CL
3.00
3.00
2.00
6.00
4.00
18.50
0.50
10.50
2.00
0.50
10.50
60
4.00
6.00
2.00
3.00
3.00
18.50
Sidewalk
Cycle Track
Verge
Access Road
Footpath
Kerb Shyness
Carriageway
Kerb Shyness
Median
Kerb Shyness
Carriageway
Kerb Shyness
Footpath
Access Road
Verge
Cycle Track
Sidewalk

Type A:Plain Terrain (6-Lane)

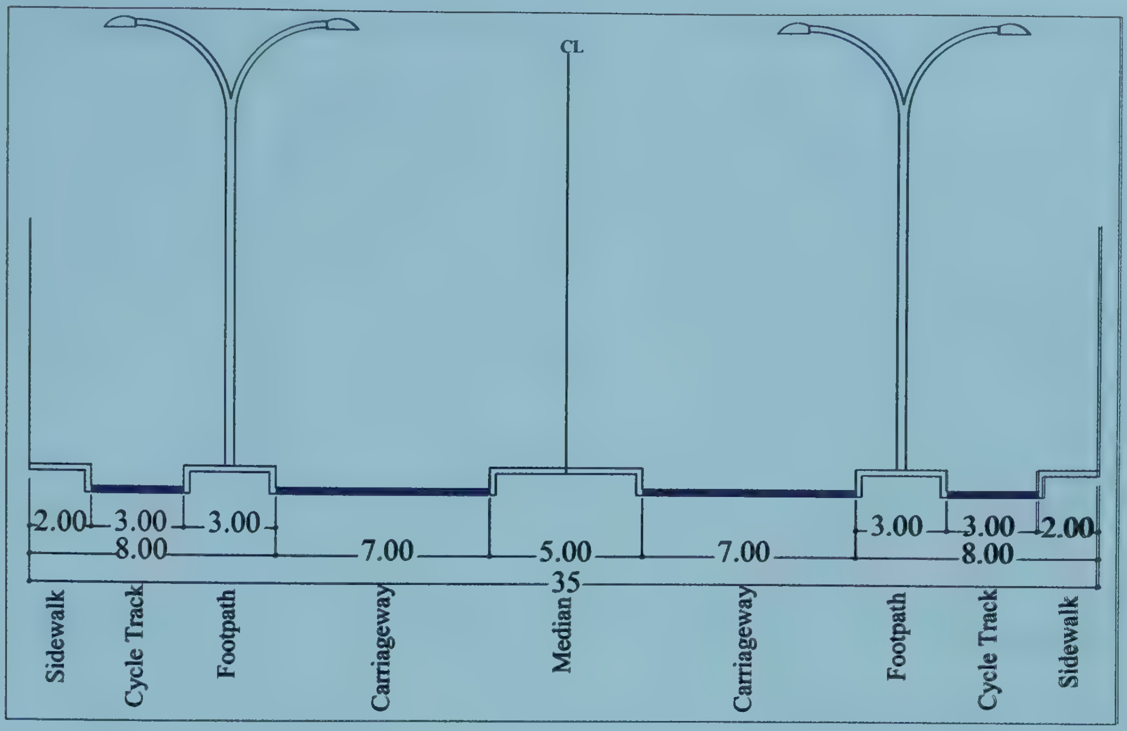

CL
2.00
2.50
2.00
3.50
3.50
13.50
10.50
0.50
2.00
0.50
10.50
50
3.50
3.50
2.00
2.50
2.00
13.50
Sidewalk
Cycle Track
Verge
Access Road
Footpath
Kerb Shyness
Carriageway
Kerb Shyness
Median
Kerb Shyness
Carriageway
Kerb Shyness
Footpath
Access Road
Verge
Cycle Track
Sidewalk

Type B: Rolling Terrain (6-Lane)

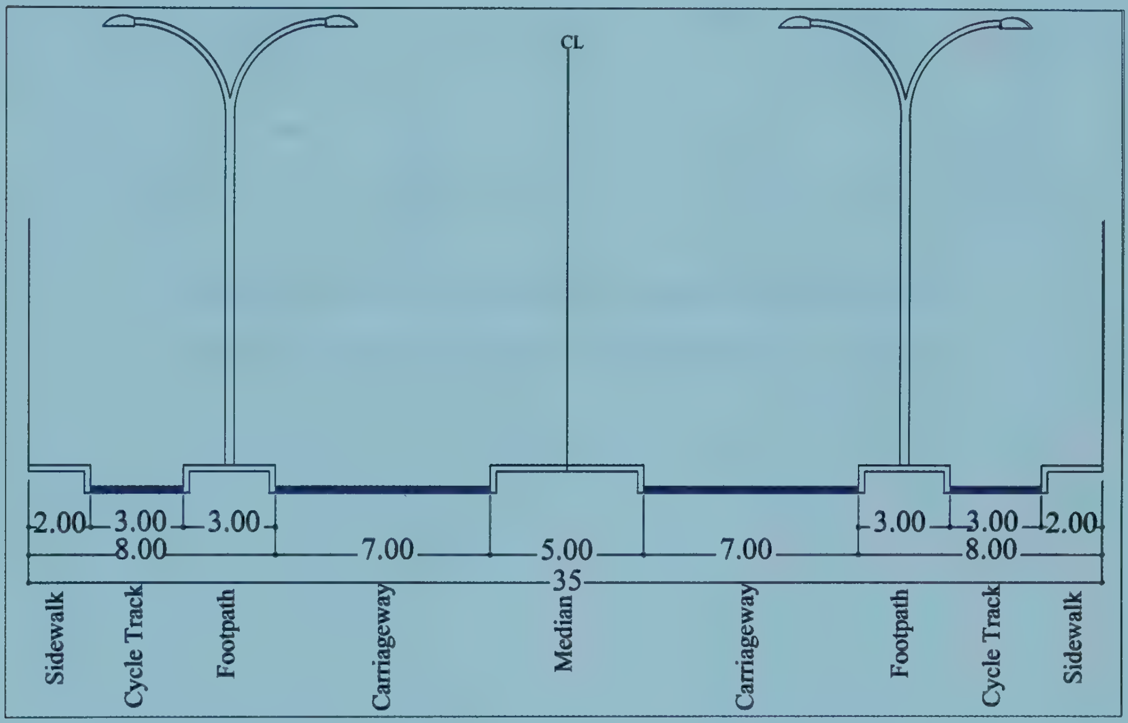

Hill Side
Catch Drain
Side Drain
Retaining Wall
3.50
6.00
3.50
13.00
Footpath With Bus Stop
Carriageway
Footpath
Side Drain
Retaining Wall
Valley Side
3.50
6.00
3.50
13.00
Footpath With Bus Stop
Carriageway
Footpath

Type C: Hilly Terrain (4-Lane)- Different Contours

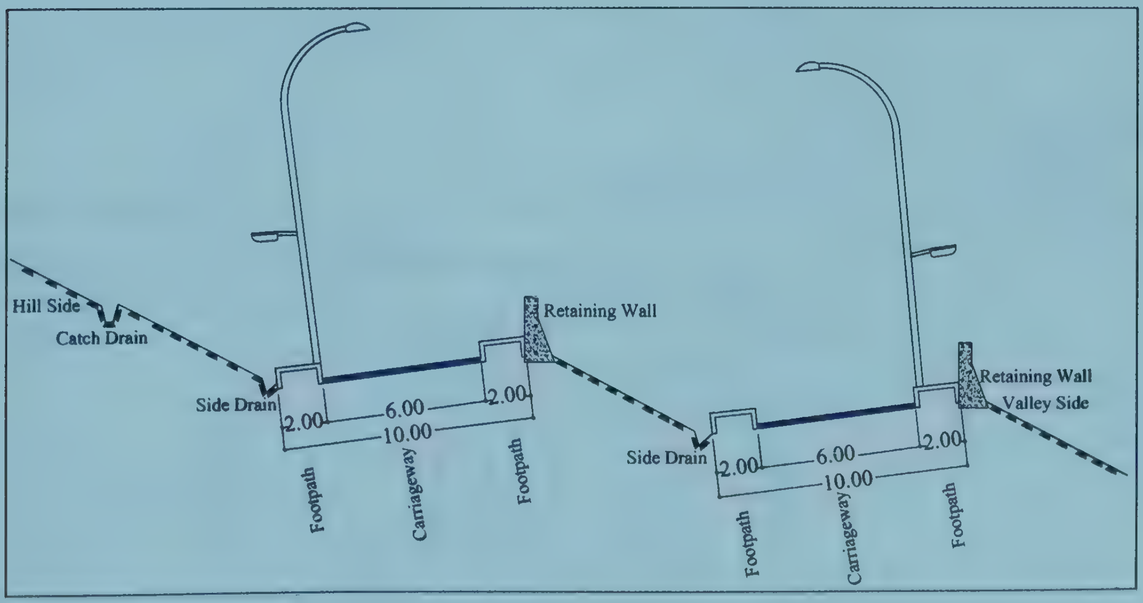
Fig. 3.1 Typical Cross Section for Arterial Road


CL
2.00
3.00
3.00
8.00
7.00
5.00
7.00
3.00
3.00
2.00
8.00
35
Sidewalk
Cycle Track
Footpath
Carriageway
Median
Carriageway
Footpath
Cycle Track
Sidewalk

Type A:Plain Terrain (4-Lane)

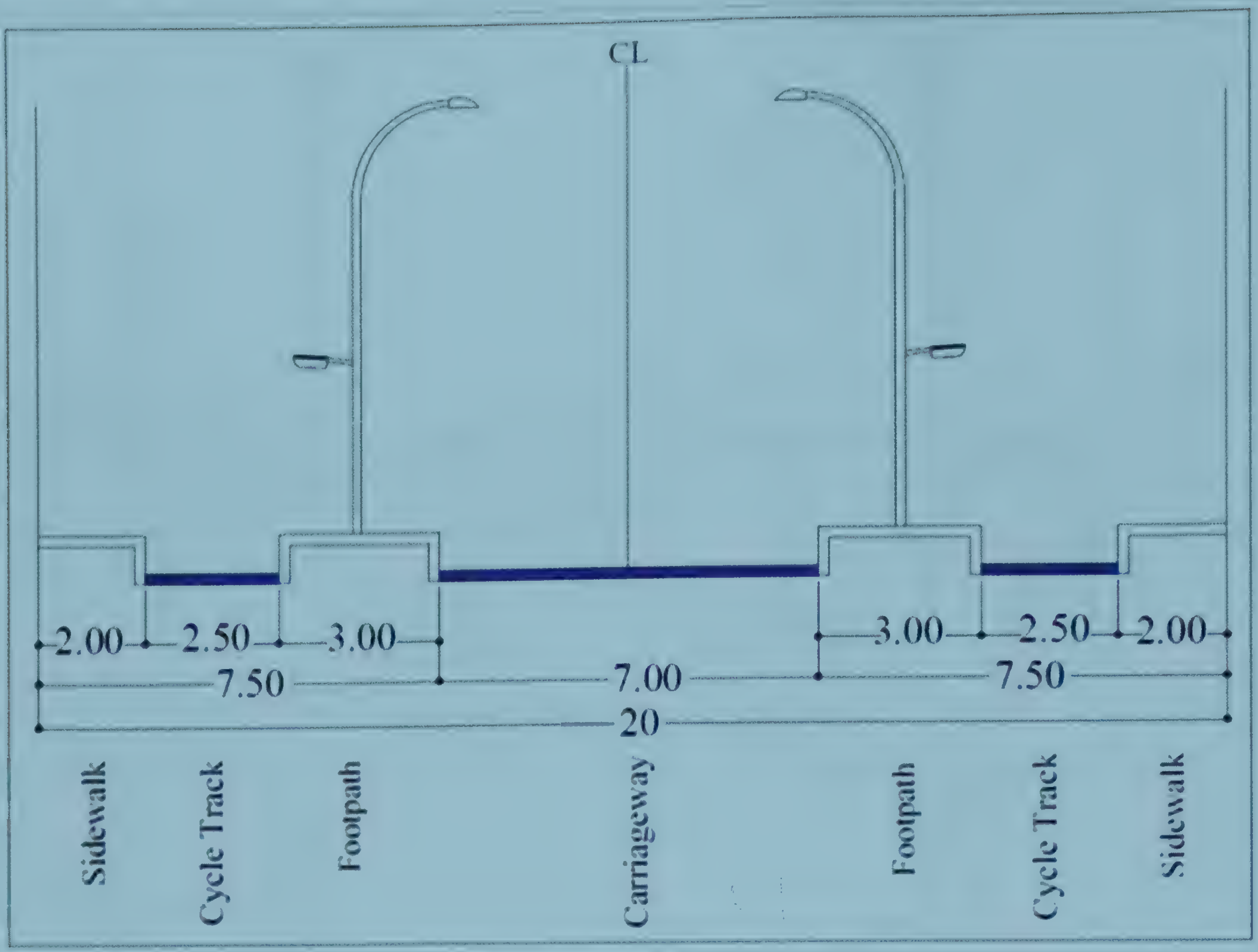

CL
2.00
3.00
3.00
8.00
7.00
5.00
7.00
3.00
3.00
2.00
8.00
35
Sidewalk
Cycle Track
Footpath
Carriageway
Median
Carriageway
Footpath
Cycle Track
Sidewalk

Type B: Rolling Terrain (4-Lane)

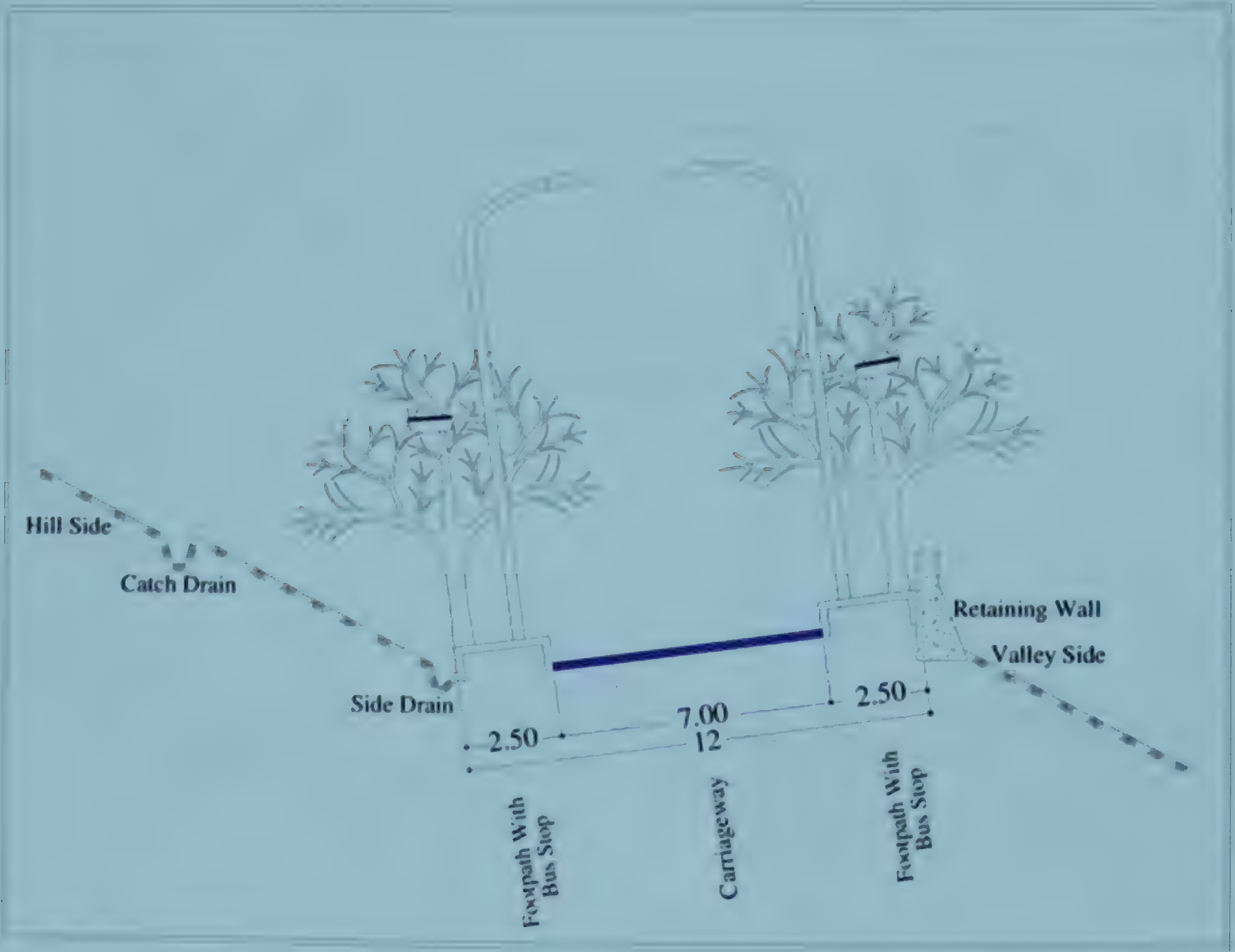

Hill Side
Catch Drain
Side Drain
2.00
6.00
10.00
2.00
Footpath
Carriageway
Footpath
Retaining Wall
Side Drain
2.00
6.00
10.00
2.00
Footpath
Carriageway
Footpath
Retaining Wall
Valley Side

Type C: Hilly Terrain (4-Lane)

Fig. 3.2 Typical Cross Section for Sub Arterial Road

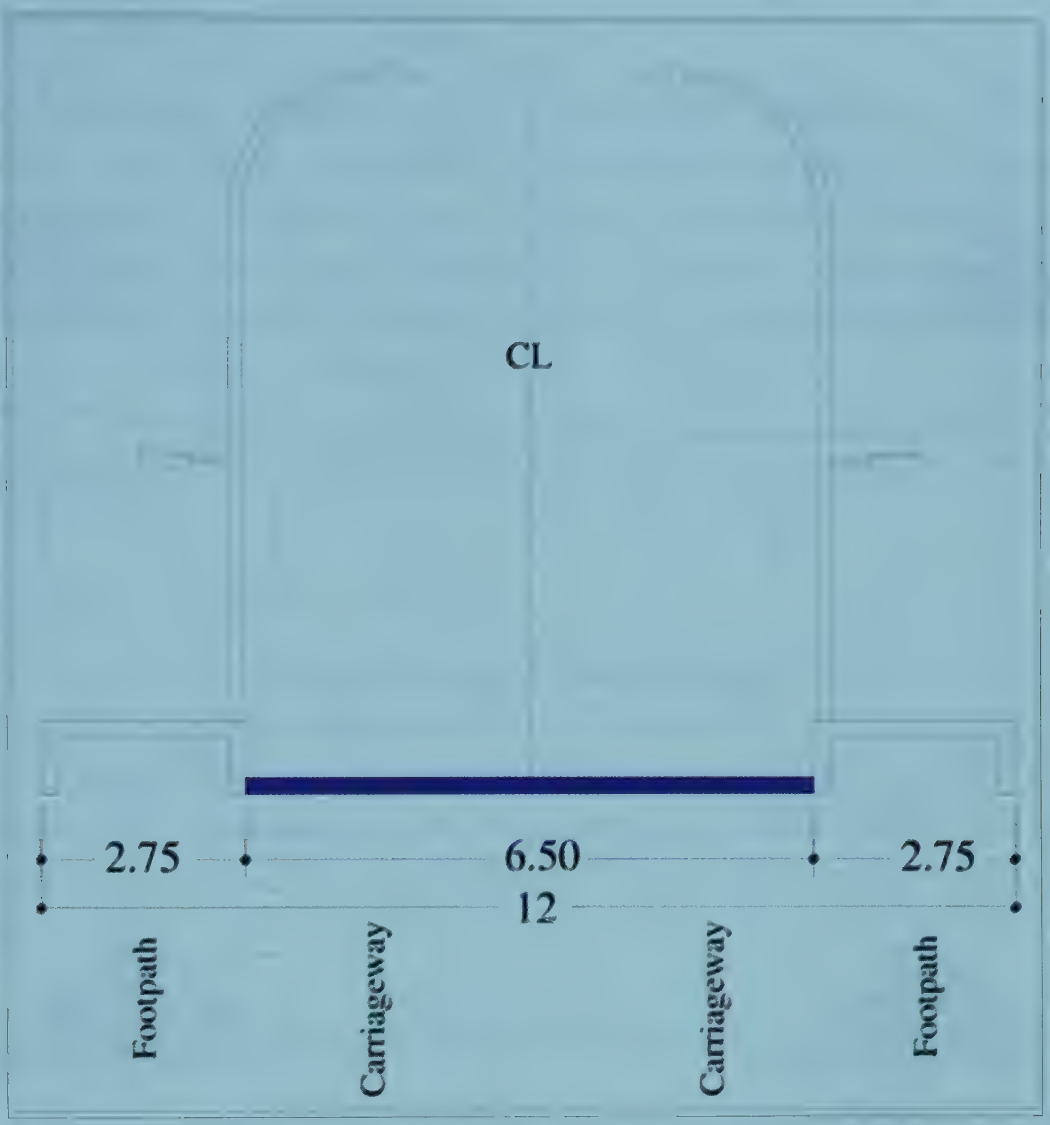

CL
2.00
2.50
3.00
7.50
7.00
3.00
2.50
2.00
7.50
20
Sidewalk
Cycle Track
Footpath
Carriageway
Footpath
Cycle Track
Sidewalk

Type A:Plain and Rolling Terrain (2-Lane)

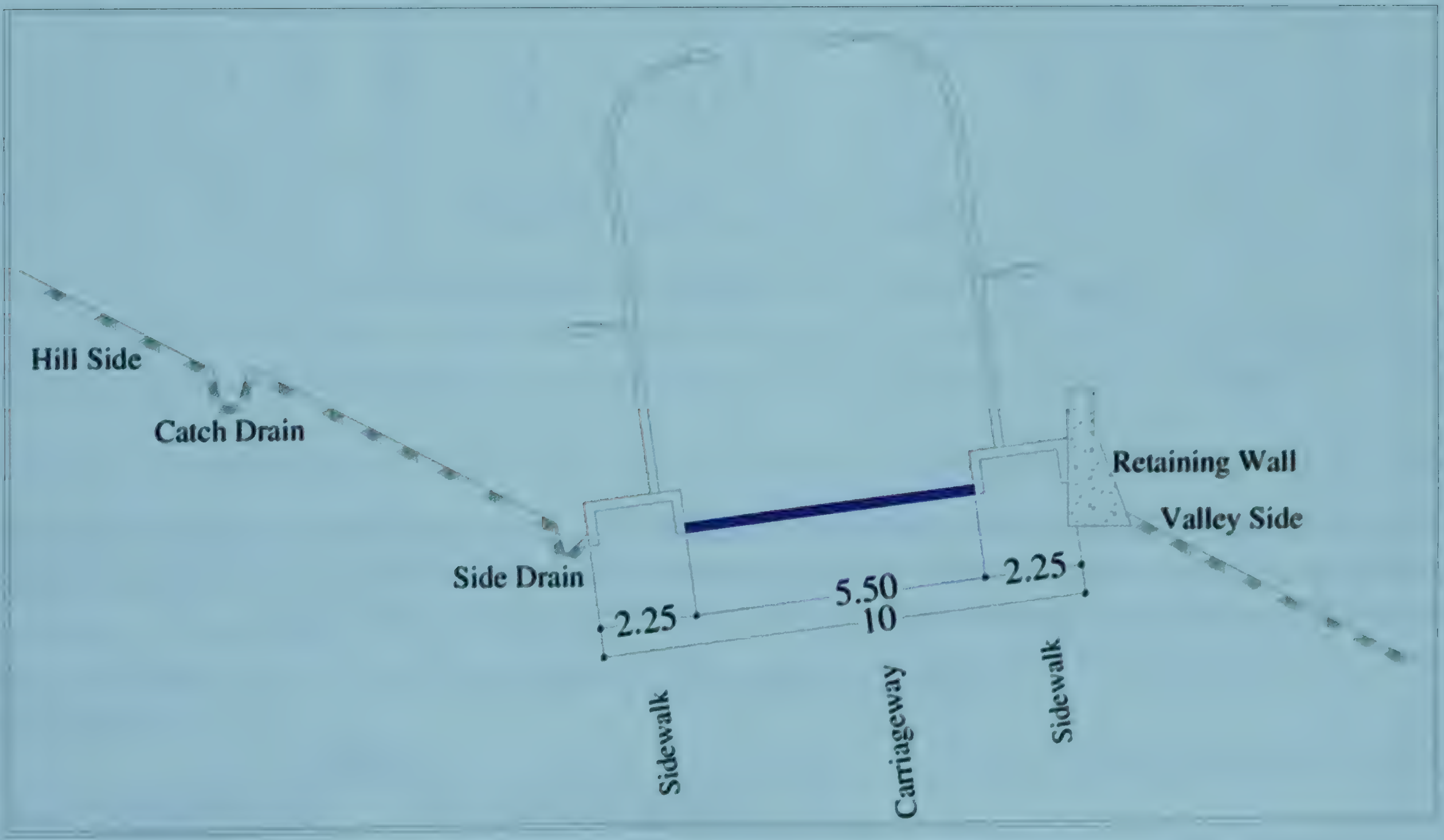

Hill Side
Catch Drain
Side Drain
Retaining Wall
Valley Side
2.50
7.00
2.50
12
Footpath With Bus Stop
Carriageway
Footpath With Bus Stop

Type B: Hilly Terrain (2-Lane)

Fig. 3.3 Typical Cross Section for Collector Street

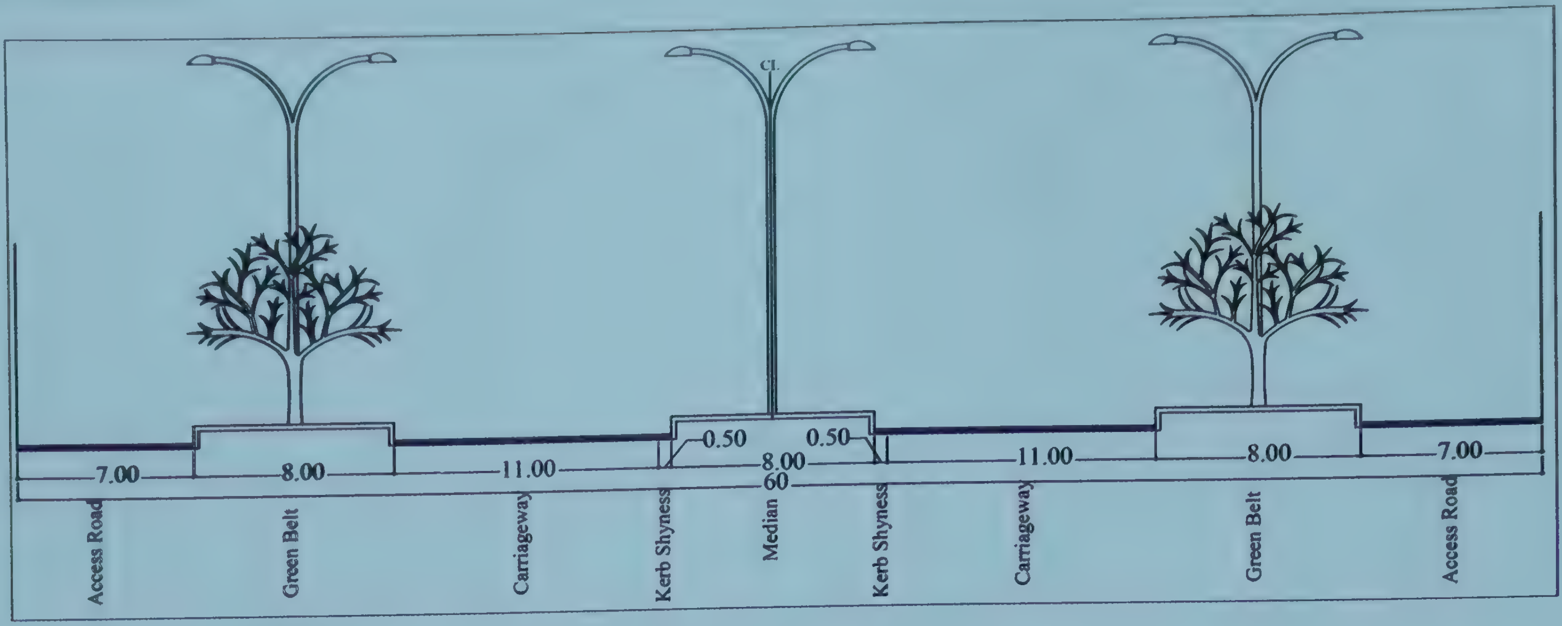

CL
2.75
6.50
2.75
12
Footpath
Carriageway
Carriageway
Footpath

Type A:Plain Terrain and Rolling Terrain

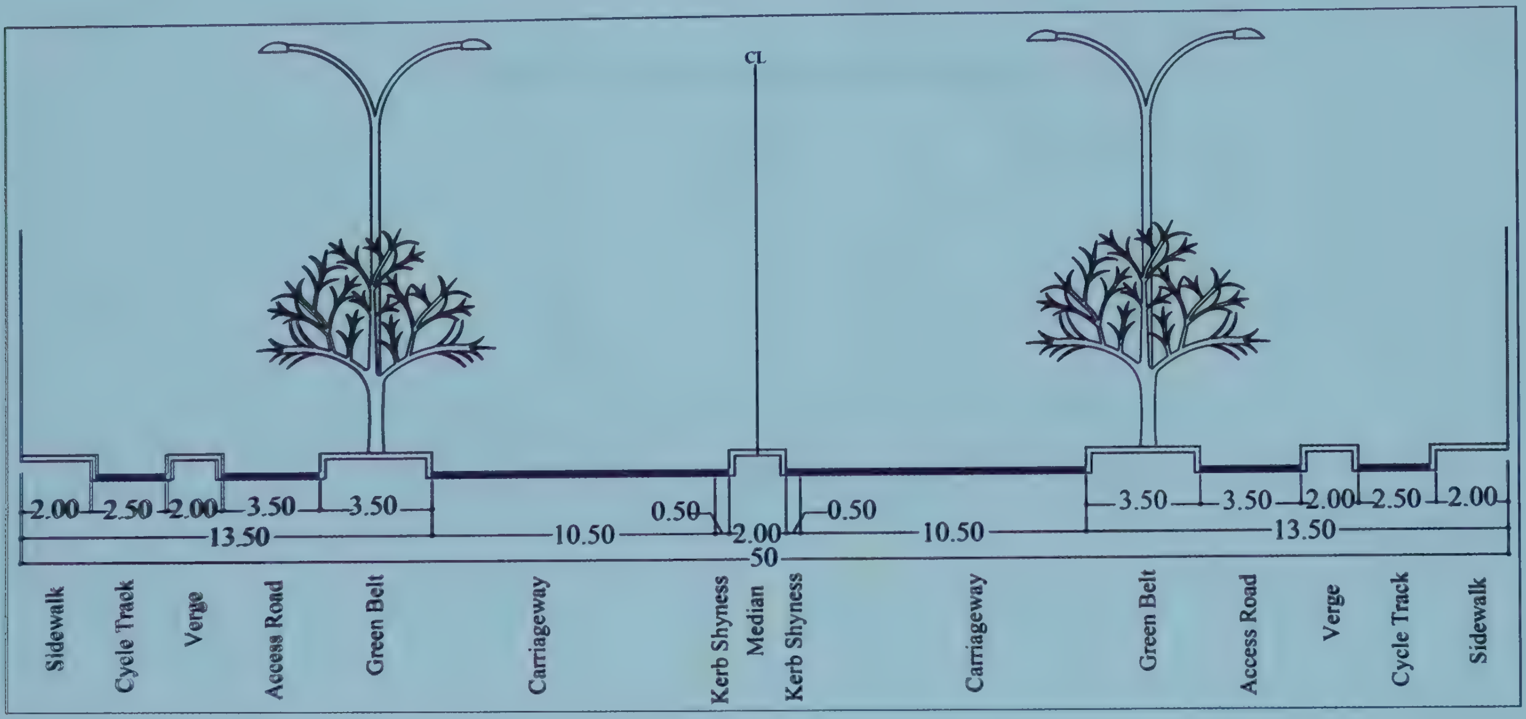

Hill Side
Catch Drain
Side Drain
Retaining Wall
Valley Side
2.25
5.50
2.25
10
Sidewalk
Carriageway
Sidewalk

Type B: Hilly Terrain

Fig. 3.4 Typical Cross Section for Local Street


CL
7.00
8.00
11.00
0.50
0.50
8.00
60
11.00
8.00
7.00
Access Road
Green Belt
Carriageway
Kerb Shyness
Median
Kerb Shyness
Carriageway
Green Belt
Access Road

Type A:Plain Terrain (6-Lane)


CL
2.00
2.50
2.00
3.50
3.50
13.50
10.50
0.50
2.00
0.50
10.50
50
3.50
3.50
2.00
2.50
2.00
13.50
Sidewalk
Cycle Track
Verge
Access Road
Green Belt
Carriageway
Kerb Shyness
Median
Kerb Shyness
Carriageway
Green Belt
Access Road
Verge
Cycle Track
Sidewalk

Type B: Rolling Terrain (6-Lane)

Fig. 3.5 Typical Cross Section for Urban Expressway

3.4 Camber

3.4.1 *Camber for Carriageway*

Camber or cross fall should be adopted as per **Table 3.3** for straight sections. Higher values of camber should be adopted in areas with high intensity of rainfall. Steeper camber should also be provided on kerbed pavement to minimise the spread of surface water flows.

Table 3.3 Camber for Carriageways

Sl. No	Surface Type	Camber	
		Heavy Rainfall Area	Light Rainfall Area
1	Thin bituminous surfacing	2.5 per cent (1 in 40)	2 per cent (1 in 50)
2	High type bituminous surfacing or cement concrete surfacing	1.7 to 2 percent (1 in 60 to 1 in 50)	2.0 to 2.5 percent (1 in 50 to 1 in 40)

3.4.2 *Camber for Shoulders*

For shoulders along unkerbed pavements, the cross fall should be 0.5 percent steeper than the slope of pavement. For paved footpaths, cross fall of 3 per cent should be adopted. For verges and unpaved areas, the cross fall should be 4 per cent. Undivided carriageways should have a crown in the middle and slope towards the edges. Divided roads may have a single crowned section or separate crowned sections for each carriageway depending on requirements of drainage and access to abutting property.

3.5 Sight Distance

3.5.1 *Stopping Sight Distance*

Stopping sight distance should be provided at all points on the road. Stopping sight distance is the total distance travelled by the driver from the time a danger is comprehended by him to the actual stop, i.e. the distance travelled during perception and brake reaction time plus the braking distance. For the purpose of measuring the stopping sight distance, the height of eye should be assumed as 1.2m and height of object as 0.15m. The design values of stopping sight distance are given in **Table 3.4**.

Table 3.4 Safe Stopping Sight Distance for various Speeds

Speed (km/h)	Safe stopping sight distance (m)
20	20
30	30
40	45
50	60
60	80
70	105
80	120

On undivided roads, intermediate sight distance which is equal to twice the stopping distance should be provided where vehicles are permitted to cross the centre line.

3.5.2 *Headlight Sight Distance for Valley Curves*

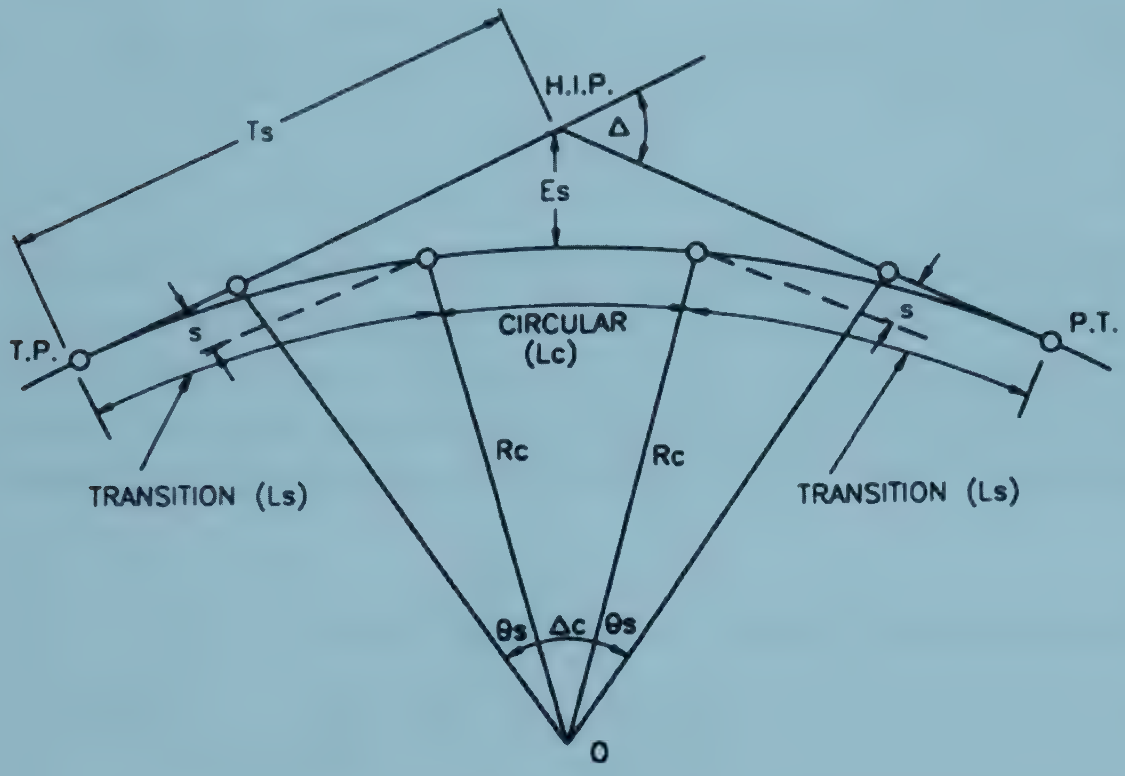
On valley curves, the design must ensure that the roadway ahead is illuminated during night travel by vehicle headlights for a sufficient length which enables the vehicle driven to apply brake to a stop, if necessary. This is known as the headlight sight distance and is equal to the safe stopping distance. From safety considerations, valley curves should be designed to provide for this visibility.

For designing valley curves, the following criteria should be followed to ensure the headlight sight distance:

- height of headlight above the road surface is 0.75m;
- the useful beam of headlight is one degree upwards from the grade of the road; and
- the height of object is nil.

3.6 Horizontal Alignment

In general, horizontal curves should consist of a circular portion flanked by spiral transitions at both ends. Design speed, super elevation and coefficient of side friction affect the design of circular curves. Length of transition curves is determined on the basis of rate of change of centrifugal acceleration and super elevation. See **Fig. 3.6** showing elements of combined circular and transition curves.



TANGENT POINT	T.P., P.T.
HORIZONTAL INTERSECTION POINT	H.I.P.
TOTAL DEVIATION ANGLE	Δ
DEVIATION AND CENTRAL ANGLE OF CIRCULAR ARC	Δc
DEVIATION ANGLE OF TRANSITION CURVE	θs
RADIUS OF CIRCULAR CURVE	Rc
SHIFT	s
TANGENT DISTANCE	Ts
APEX DISTANCE	Es
LENGTH OF TRANSITION	Ls
LENGTH OF CIRCULAR CURVE	Lc

Fig. 3.6 Elements of a Combined Circular and Transition Curve

3.6.1 *Super Elevation*

Super elevation required on horizontal curves should be calculated from the following formula. This assumes the centrifugal force corresponding to three-fourth the design speed is balanced by super elevation and the remaining one fourth counteracted by side friction:

$$e = \frac{V^2}{225R}$$

where

e = super elevation in metre per metre
V = speed in km/hr, and
R = radius in metres

Super elevation obtained from the above expression should be limited to 7 per cent. However, on urban sections with frequent intersections, it will be desirable to limit the super elevation to 4 per cent for convenience in construction and for facilitating easy and safe turning movement of vehicles. **Table 3.5** gives the radii of horizontal curves for different camber rates beyond which super elevation is not required.

Table 3.5 Radii beyond which Super Elevation is not required

Design Speed (km/hr)	Radius (m) for camber of		
	2.5 percent	2 percent	1.7 percent
20	70	90	100
30	160	200	240
40	280	350	420
50	450	550	650
60	640	800	940
70	870	1090	1280
80	1100	1400	1700

3.6.2 *Minimum Curve Radius*

Radius of curvature depends upon speed, super elevation, and side friction between vehicle and pavement. Minimum radii of horizontal curves for different design speeds with maximum super elevation limited to 4 percent and 7 percent are given in **Table 3.6**.

Table 3.6 Minimum Radii of Horizontal Curves

Design Speed (km/hr)	Minimum radius (m) when super elevation is limited to	
	7 percent	4 percent
20	15	20
30	30	40
40	60	70
50	90	105
60	130	150
70	175	200
80	230	265

3.6.3 *Set-back Distance at Horizontal Curves*

Physical obstructions on the inside of horizontal curves often restrict sight distance. Sight areas on horizontal curves should be such as to provide driver with sight distance equal to the design stopping distance on curve.

3.6.4 *Transition Curves*

Transition curves are necessary for a vehicle to have smooth entry from a straight section into a circular curve. The transition curves also improve aesthetic appearance of the road besides permitting gradual application of the super elevation and extra widening of carriageway needed at the horizontal curves. Spiral curve should be used for this purpose. Minimum length of the transition curve should be determined from the following two considerations and the larger of the two values adopted for design:

i) The rate of change of centrifugal acceleration should not cause discomfort to drivers. From this consideration, the length of transition curve is given by:

$$L_s = \frac{0.0215V^2}{CR}$$

where L_s = length of transition curve in metres

V = speed in km/hr

R = radius of circular curve in metres

C = $\frac{80}{75+V}$

ii) The rate of change of super elevation (i.e. the longitudinal grade developed at the pavement edge compared to through grade along the centre line) should be such as not to cause discomfort to travellers or to make the road appear unsightly. This rate of change should not be steeper than 1 in 150. The formula for minimum length of transition on this basis with super elevation limited to 7 percent works out to:

For Plain and Rolling Terrain $L_s = \frac{2.7V^2}{R}$

For Hilly Terrain $L_s = \frac{1.0\,V^2}{R}$

Having regard to the above considerations, the minimum transition lengths for different speeds and curve radii are given in **Table 3.7**.

Table 3.7 Minimum Transition Lengths (in metres) for Different Speeds and Curve Radii

Plain and Rolling Terrain							**Hilly Terrain**					
Curve Radius R (metre)	**Design Speed (km/hr)**						**Curve Radius R (metre)**	**Design Speed (km/hr)**				
	30	**40**	**50**	**60**	**70**	**80**		**20**	**30**	**40**	**50**	**60**
15							15	30				
20							20	20				
25	NA						25	20	NA			
30	80						30	15	30	NA		
50	50	NA	NA				50	15	20	40	NA	NA
100	25	45	70	NA			100	NR	15	20	45	40
150	20	30	45	65			150		15	15	30	25
200	15	25	35	50	NA	NA	200		NR	15	20	20
250	NR	20	30	40	85	85	250			15	15	15
300		NR	25	35	75	75	300			NR	15	15
400			20	25	55	55	400				15	15
500			NR	20	45	45	500				NR	15
600				20	35	35	600					NR
800				NR	30	30	800					
1000					30	30	1000					

NA-Not applicable

NR-Transition not required

3.6.5 *Widening of Carriageway on Curves*

At sharp horizontal curves, it is necessary to widen the carriageway to provide for safe passage of vehicles. The widening required has two components: (i) mechanical widening to compensate for the extra width occupied by a vehicle on the curve due to tracking of the rear wheels, and (ii) psychological widening to permit easy crossing of vehicles since vehicles in a lane tend to wander more on a curve than on a straight reach. Based on the above considerations, the extra width of carriageway to be provided at horizontal curves on single and two-lane roads is given in **Table 3.8**. For multi-lane roads, the pavement widening may be calculated by adding half the widening for two-lane roads to each lane.

Table 3.8 Extra Width of Pavement at Horizontal Curves

	Extra width (m) for radius of curve					
	Upto 20m	**21m to 40m**	**41m to 60m**	**61m to 100m**	**101m to 300m**	**Above 300m**
Two Lane	1.5	1.5	1.2	0.9	0.6	Nil
Single-Lane	0.9	0.6	0.6	Nil	Nil	Nil

3.7 Vertical Alignment

Vertical alignment in urban areas is governed by need to match building line and entrance line levels and levels of intersections and median openings.

3.7.1 *Gradient*

Most urban roads carry mixed traffic including slow moving vehicles like bicycles and animal/hand carts. Besides this, urban roads generally have intersections at frequent intervals. In view of this, as a general rule, a gradient of 4 percent should be considered the maximum for urban roads. On roads carrying predominantly slow moving traffic, however, the gradient should desirably not exceed 2 percent. At intersections, the road should be as near level as possible. As the urban roads are generally kerbed, it would be desirable to ensure a minimum gradient as indicated in **Table 3.9** for facilitating longitudinal drainage.

Table 3.9 Recommended Minimum Gradients

Design Element	Gradient	
	Desirable minimum (percent)	**Absolute minimum (percent)**
Kerbed Pavements	0.5	0.3
Side Ditches (lined)	0.5	0.2

3.7.2 *Vertical Curves*

Vertical curves should be provided at all grade changes exceeding those indicated in **Table 3.10**. The minimum lengths of vertical curves for satisfactory aberrance and maximum grade change not requiring a vertical curve are also given in **Table 3.10**.

Table 3.10 Minimum Length of Vertical Curves

Design Speed (km/hr)	Maximum grade change (percent) not requiring a vertical curve	Minimum length of vertical curve (m)
20	1.5	15
30	1.5	15
40	1.2	20
50	1.0	30
60	0.8	40
70	0.6	50
80	0.6	50

Summit Curves

A vertical curve with convexity upwards is called a summit curve. Summit curves in urban areas should be designed for safe stopping sight distance and they should be coordinated with horizontal curvature. Broken-back profiles should be avoided and wherever possible, approaches to bridges less than 30m width should be designed to fit a single vertical curve.

Length of the summit curve should be calculated on the basis of the following formulae:

i) When the length of the curve exceeds the required sight distance i.e., L is greater than S

$$L = \frac{NS^2}{4.4}$$

where N = deviation angle, i.e., the algebraic difference between two grades

L = length of vertical curve in metres

S = sight distance in metres

ii) When the length of the curve is less than the required sight distance i.e., L is less than S

$$L = 2S - \frac{4.4}{N}$$

Valley Curves

A vertical curve concave upwards is known as a valley curve, dip or sag. Valley curves on unlighted urban roads should be such that for night travel, the headlight beam distance is the same as the stopping sight distance. In accordance with this criterion, the length of the curve may be calculated as under:

i) When the length of the curve exceeds the sight distance

$$L = \frac{NS^2}{1.50 + 0.035S}$$

ii) When the length of the curve is less than the required sight distance

The length of curves for various values of sight distance and deviation angles have been calculated as per above formulae

$$L = 2S - \frac{1.50 + 0.035S}{N}$$

Valley curves on urban roads which are usually lit during the hours of darkness may be designed merely for vertical acceleration of 0.5 g for riding comfort and in that case minimum lengths given in **Table 3.10** will suffice.

3.8 Co-ordination of Horizontal and Vertical Alignments

Horizontal and Vertical alignments should not be designed independently. They complement each other and poorly designed combination can aggravate the deficiencies of each. The design should be visualised in the perspective to achieve a flowing and pleasing view from the road. The broad principles given below should be followed in alignment co-ordination:

i. The degrees of curvature should be in proper balance with the gradients. Straight alignment or flat horizontal curves at the expense of steep or long grades, or excessive curvature in a road with flat grades, do not constitute balanced designs and should be avoided.

ii. Vertical curve superimposed upon horizontal curve gives a pleasing effect. As such the vertical and horizontal curves should coincide as far as possible and their lengths should be more or less equal. If this is difficult to achieve for any reason, the horizontal curve should be somewhat longer than the vertical curve.

iii. Sharp horizontal curves should be avoided at or near the apex of pronounced summit/ sag vertical curves from safety considerations.

3.9 Lateral and Vertical Clearances

Lateral and Vertical Clearances are required to be provided for overhanging loads and the tilting of vehicle towards obstruction by cross fall or super elevation of carriageway and for kerb shyness. Standards for lateral clearances for underpasses on urban roads are given in IRC:54 "Lateral and Vertical Clearances at Underpasses for Vehicular Traffic". The same are recommended between edge of carriageway and obstruction on footpath, verge or central reserve. Where an obstruction is located on the inside of a bend, a greater clearance than that specified may be required to ensure that the sight distance is not less than the minimum.

Underpass for Vehicles

Lateral Clearance: The lateral clearance from the edge of pavement should be as follows:

a) Pavement without footpath

Minimum clearance from the edge of pavement

- Arterial and sub-arterial: 1.0m
- Collector and local streets: 0.5m

b) Pavement with footpath

- No extra clearance beyond the footpath is necessary.

c) Clearance on divided carriageway

The left side clearances should be as above. The right side clearance to the face of any structure in the central median shall be as follows:

- Arterial: 1m from the edge of pavement
- Collector and local streets: 0.5m from the edge of pavement

Vertical Clearance: The minimum vertical clearance on urban roads should be 5.5m.

3.10 Design of Public Utilities

Careful location and planning of physical infrastructure services and urban utilities is critical in order to allow easy access for regular repair and maintenance of utilities, while causing minimum disruption or disturbance to other street users. For details refer IRC:SP:118 "Guidelines on Planning and Development of Urban Roads and Streets".

3.11 Topographical Data

Following topographical surveys are recommended for collection of topographical data for urban roads to improve the existing road/street geometric elements and/or to propose new infrastructure facilities.

Stereo Satellite Data: Stereo Satellite Imagery is a form of Stereoscopy or 3D image. Stereo image pairs are used to make Digital Elevation Models (DEMs) and Digital Surface Models (DSM).Stereo satellite data can be procured through National Remote Sensing Center (NRSC) of Indian Space Research Organisation (ISRO).

Total Station Survey Data: Total Station (TS) is an all in one instrument fulfilling the needs of a theodolite, a leveling instrument and a DISTOMAT (electronic distance measurement instrument). TS also has an inbuilt software which makes all the necessary computations. Microprocessor in TS will support software to perform various mathematical operations such as multiple angle and distance measurements, horizontal and vertical distances, and corrections for atmospheric and instrumental corrections. The detachable data cards and data transferring equipments provide support to transfer the data. Using TS and mapping Software, the maps can be created automatically.

LiDAR Data: Light Distance And Ranging (LiDAR) is a technology for measuring the positions of physical objects rapidly. LiDAR uses a laser beam to measure the distance from an object to the scanner, and mechanical-optical mount to scan the laser across a scene accurately. LiDAR is useful not only because it can provide accurate positions over large areas, but also because it is fast, LiDAR can collect tens of thousands to over a million positions per second. Collecting location based data at this level of detail through traditional surveying would take more time.

LiDAR data can be collected from airborne or terrestrial vehicles, from fixed positions, usually on a tripod, and offshore platforms. In terrestrial acquisition, the LiDAR unit is mounted either on a tripod or on a vehicle. With terrestrial mobile systems, a coupled GPS-IMU solution is needed to track the device position during data acquisition. Ground control GPS locations are also used with mobile systems both for calibration and quality assessment. With tripod mounted systems, GPS control can be either from a GPS on the unit, plus one or more control points on the ground to provide geometry, or from multiple GPS targets on the ground.

Unmanned Aerial Survey (UAV) Data: An Unmanned Aerial Vehicle (UAV), commonly known as a drone, as an unmanned aircraft system or by several other names, is an aircraft without a human pilot aboard. The flight of UAVs may operate with various degrees of autonomy either under remote control by a human operator, or fully or intermittently autonomously, by onboard computers.

3.12 Geometric Design Software

Most public agencies and consulting firms engaged in a large volume of design work now employ computer software to assist in the design of transportation facilities. Such design packages are used in conjunction with Computer-Aided Drawing (CAD) software to produce facility plans that include horizontal and vertical alignments. The most common arrangement is for the design and drawing programs to run simultaneously, with the design program calling routines from the drawing program as needed to construct the drawings. It is also possible to have the design and drawing programs communicate by exchanging graphic files. The process of designing a transportation facility with a design software package usually begins with a Digital Terrain Model (DTM) obtained from topographical survey data. If a DTM is available, this may be used to construct a contour map, slope aspect map to be used as a base map for design of geometric elements. Other features, such as existing structures, may be added to the base map by means of the drawing program.

Once the base map is completed, the user begins to design the facility by defining horizontal and vertical alignments. The horizontal alignment will be defined first; based on this, the design program will display existing elevations along the center line or other primary reference line. A single project may have multiple alignments; for instance, divided roadways with wide medians can be designed with separate horizontal and vertical alignments, and separate ditch profiles may be specified. In constructing alignments including horizontal and vertical, critical points such as Point of Intersections (P.I.) may be established either by specifying coordinates or (in the case of vertical alignment) stations and elevations, by projecting known directions or grades and distances from existing points, or visually, by dragging the point with a mouse or other digitizing device.

The design software also will usually provide for automatic stationing of alignments and fitting of standard features such as circular horizontal curves, spirals, and parabolic vertical curves. The user also defines templates, describing the facility cross section. These define the geometric cross section, ditch shapes, and earthwork cross-slopes.

The design program has the capability of calculating transitions between successive templates in the case of multiple templates. Where there are super elevated curves, the user enters the location and other details of super elevation transitions, and the program modifies the cross-section templates to account for the super elevation.

Once alignments and templates are defined, the program constructs a single three-dimensional mathematical representation of the facility from them. This can be used to produce three-dimensional views. These may be rotated and zoomed to produce three-dimensional drawings of the facility from any point of view. Also, once alignments and templates are established, the program calculates earthwork cross sections by means of a digital terrain model of base model and design model. Once earthwork cross sections are established, the design program can calculate earthwork volumes

Final versions of plans may be prepared by using the drawing program to add any features or notes not supplied by the design program.

Advantages of using software packages to design transportation facilities include:

- Design software provides for rapid redesign of facilities; in particular, earthwork quantities for new alignments may be calculated very rapidly. This is a major advantage, since calculation of earthwork quantities by hand is a laborious process
- Design software provides the ability to easily visualize facilities in three dimensions. Because three-dimensional representations may be constructed from any viewpoint and on any orientation, it is easy to evaluate the appearance of the facility.
- With the design and drawing software, drawings may be rescaled rapidly, and multiple versions of drawings emphasizing different features may be readily produced. Drawing programs allow graphical objects to be grouped into different layers.

CHAPTER 4

INTERSECTIONS AND INTERCHANGES

4.1 Introduction

Road intersections are critical elements of a road stretch. In urban areas, availability of land and sight distance are an important consideration. Moreover, the design of intersections must also factor in the requirements of pedestrians and cyclists to ensure their safe and smooth movement. **Fig. 4.1** shows the hierarchy of intersections.

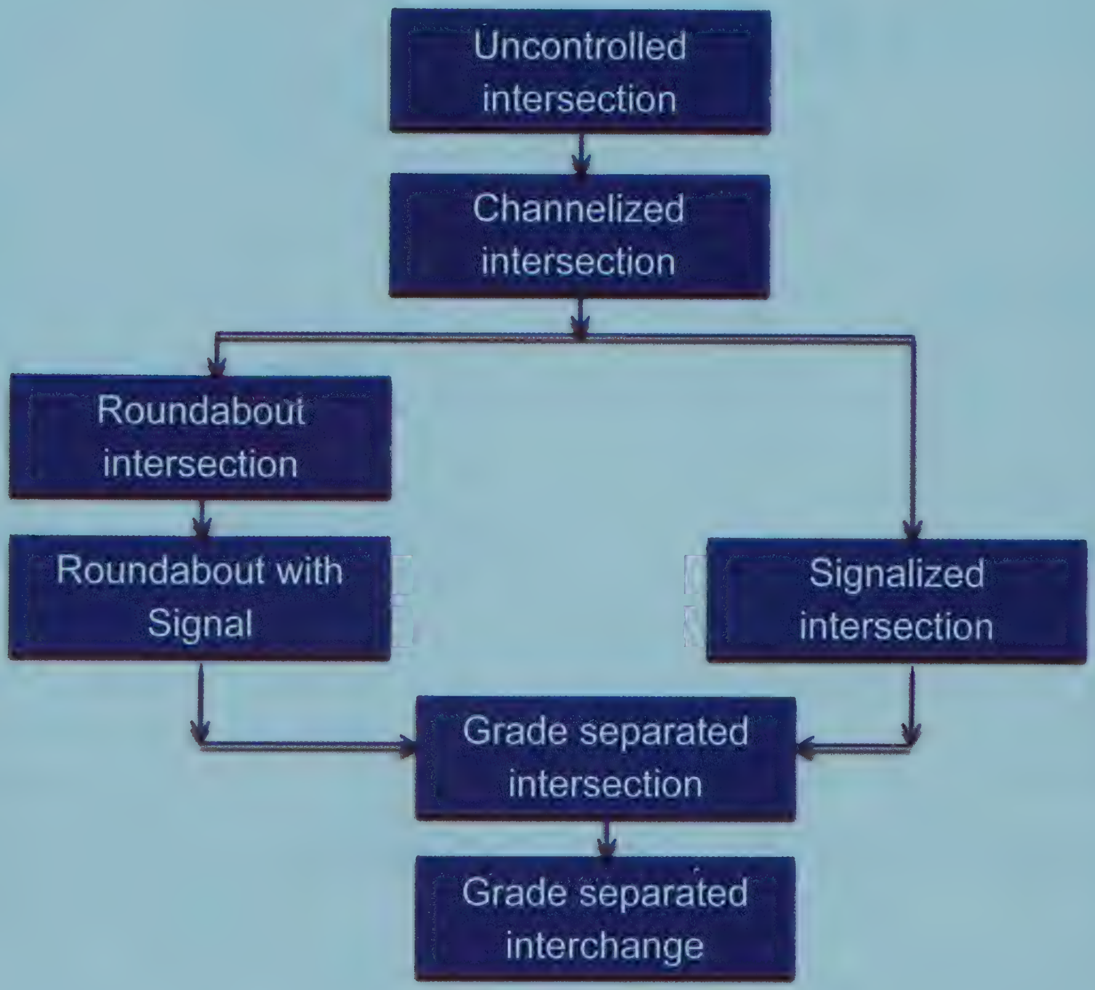

Uncontrolled intersection
Channelized intersection
Roundabout intersection
Roundabout with Signal
Signalized intersection
Grade separated intersection
Grade separated interchange

Fig. 4.1 Hierarchy of Intersections

This chapter draws heavily on the IRC Special Publications IRC:SP:41 on intersections, IRC:SP:65 on roundabouts and IRC:SP:92 on interchanges.

4.2 Intersections

4.2.1 *Types*

Generally, there are three types of intersections depending upon traffic conditions

i) Uncontrolled Intersection
ii) Intersection with Priority Control
iii) Signalised Intersection

Then, intersections are 3-Leg, 4-Leg and Roundabouts/Rotaries depending upon the location and number of intersecting arms. For details refer to IRC:SP:41. **Fig. 4.2** captures the various shapes

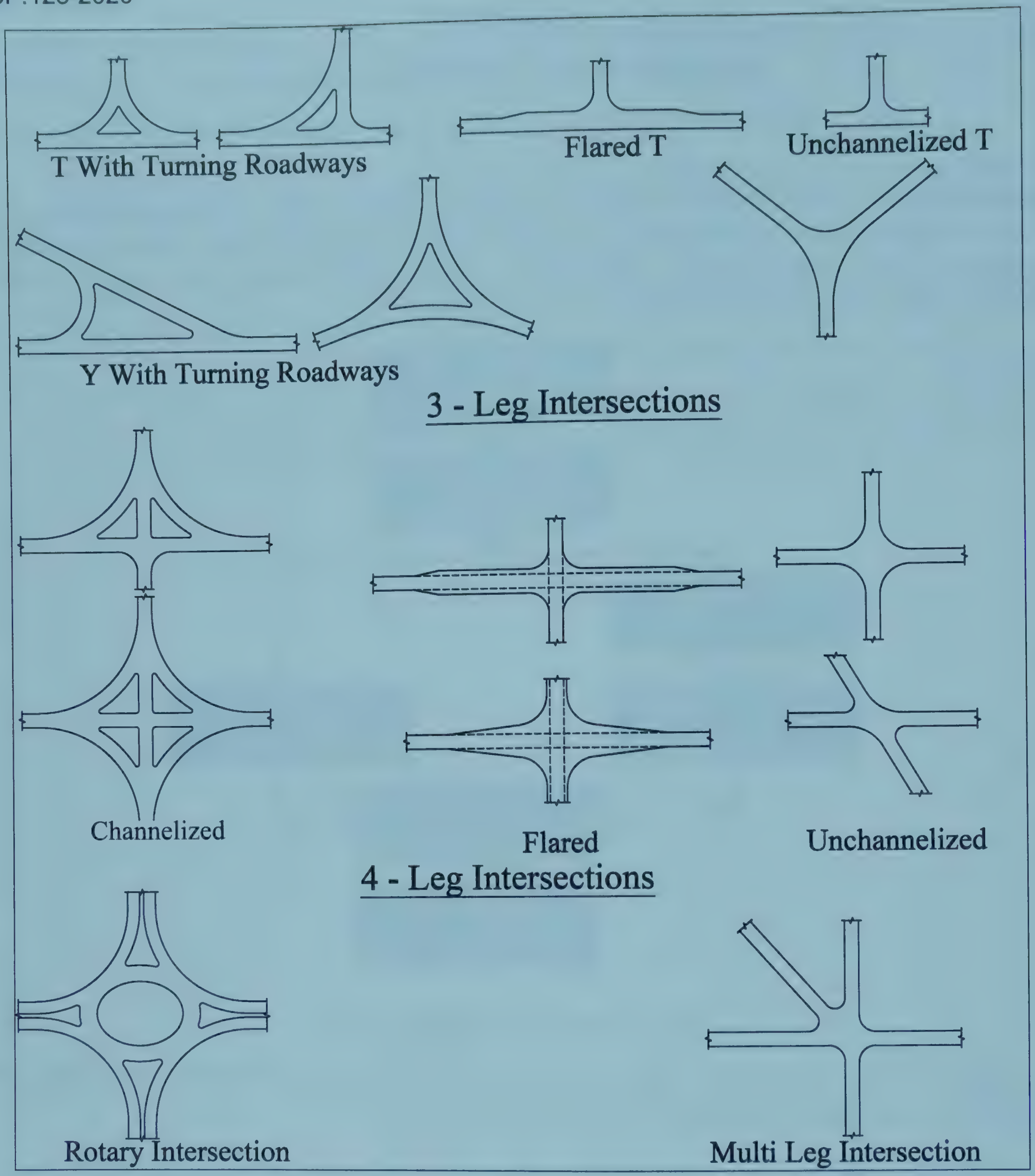

T With Turning Roadways
Flared T
Unchannelized T
Y With Turning Roadways
3 - Leg Intersections
Channelized
Flared
Unchannelized
4 - Leg Intersections
Rotary Intersection
Multi Leg Intersection

Fig. 4.2 General Types of Intersections

4.2.2 *Basic Design Principles*

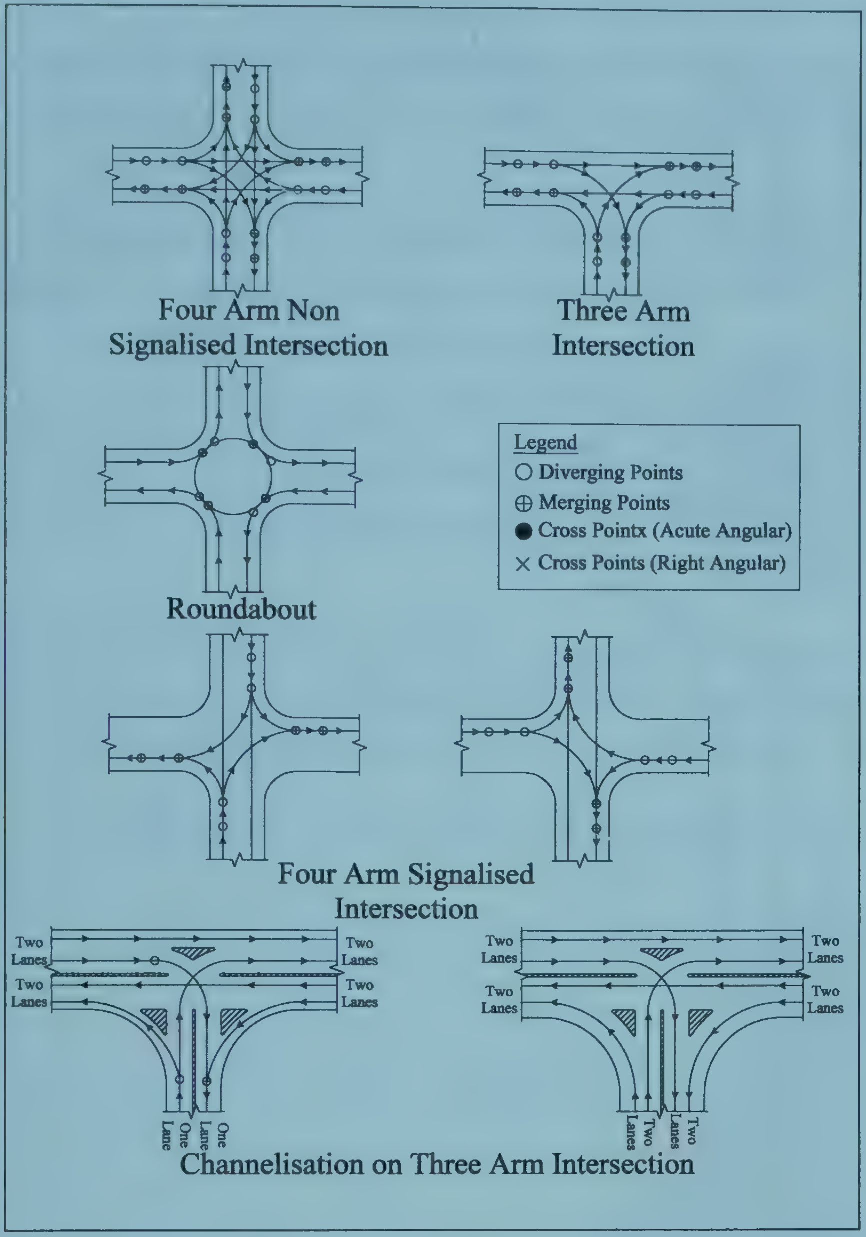
i) Simplicity and Uniformity: As far as possible, design should be simple and uniform. Capabilities and limitations of drivers, pedestrians, cyclists and vehicles need to be factored in design.

ii) Minimise Conflict Points: Attempt should be made to reduce the conflict points subject to limitation of land. This can be done by

a) Space Separation: Channelising islands, staggering the junction.

b) Time Separation: Traffic Signals

A few illustrations are reproduced from IRC:SP:41 in **Figs. 4.3, 4.4** and **4.5**.


Four Arm Non Signalised Intersection
Three Arm Intersection
Roundabout
Legend
○ Diverging Points
⊕ Merging Points
● Cross Pointx (Acute Angular)
× Cross Points (Right Angular)
Four Arm Signalised Intersection
Two Lanes
Two Lanes
Two Lanes
Two Lanes
One Lane
One Lane
One Lane
Two Lanes
Two Lanes
Two Lanes
Two Lanes
Two Lanes
Two Lanes
Two Lanes
Channelisation on Three Arm Intersection

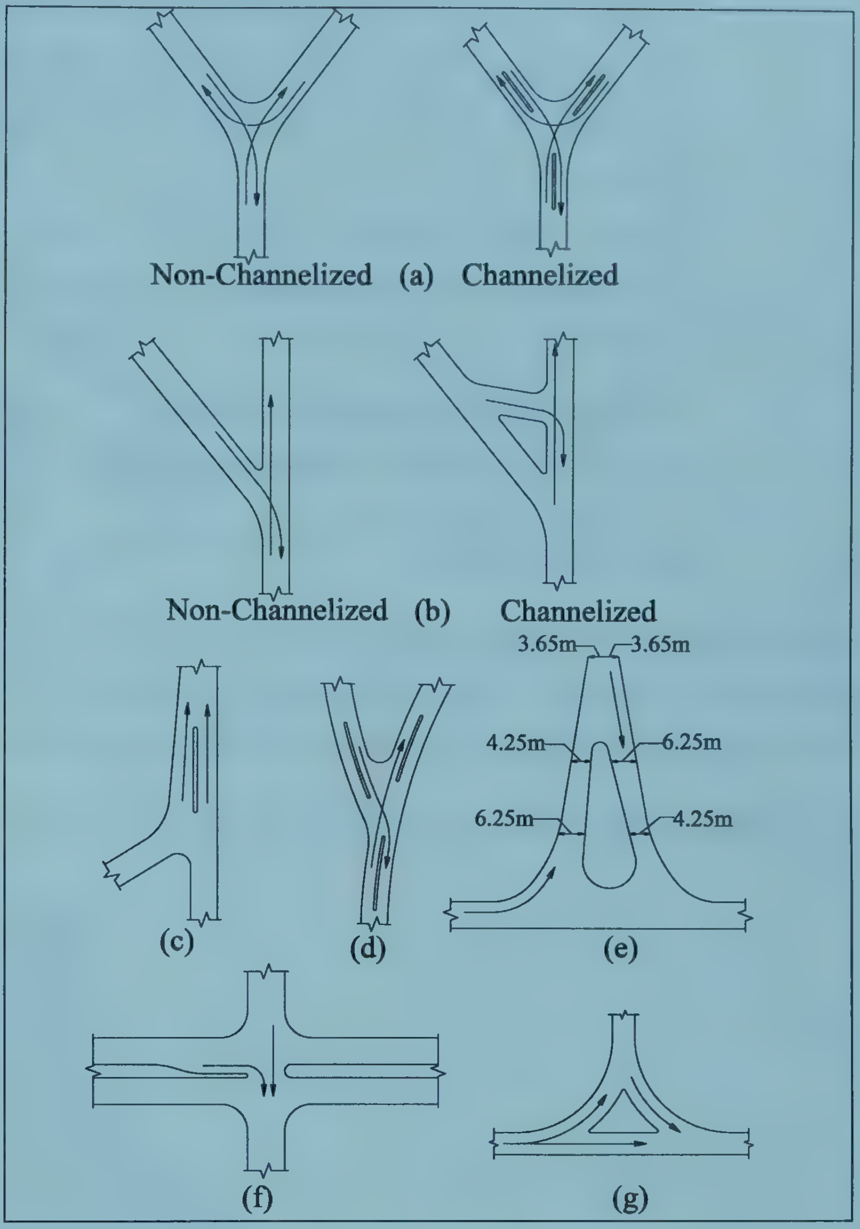

Non-Channelized
(a)
Channelized
Non-Channelized
(b)
Channelized
3.65m
3.65m
4.25m
6.25m
6.25m
4.25m
(c)
(d)
(e)
(f)
(g)

Fig. 4.3 Potential Conflict Points at Intersections

Fig. 4.4 Channelizing Islands

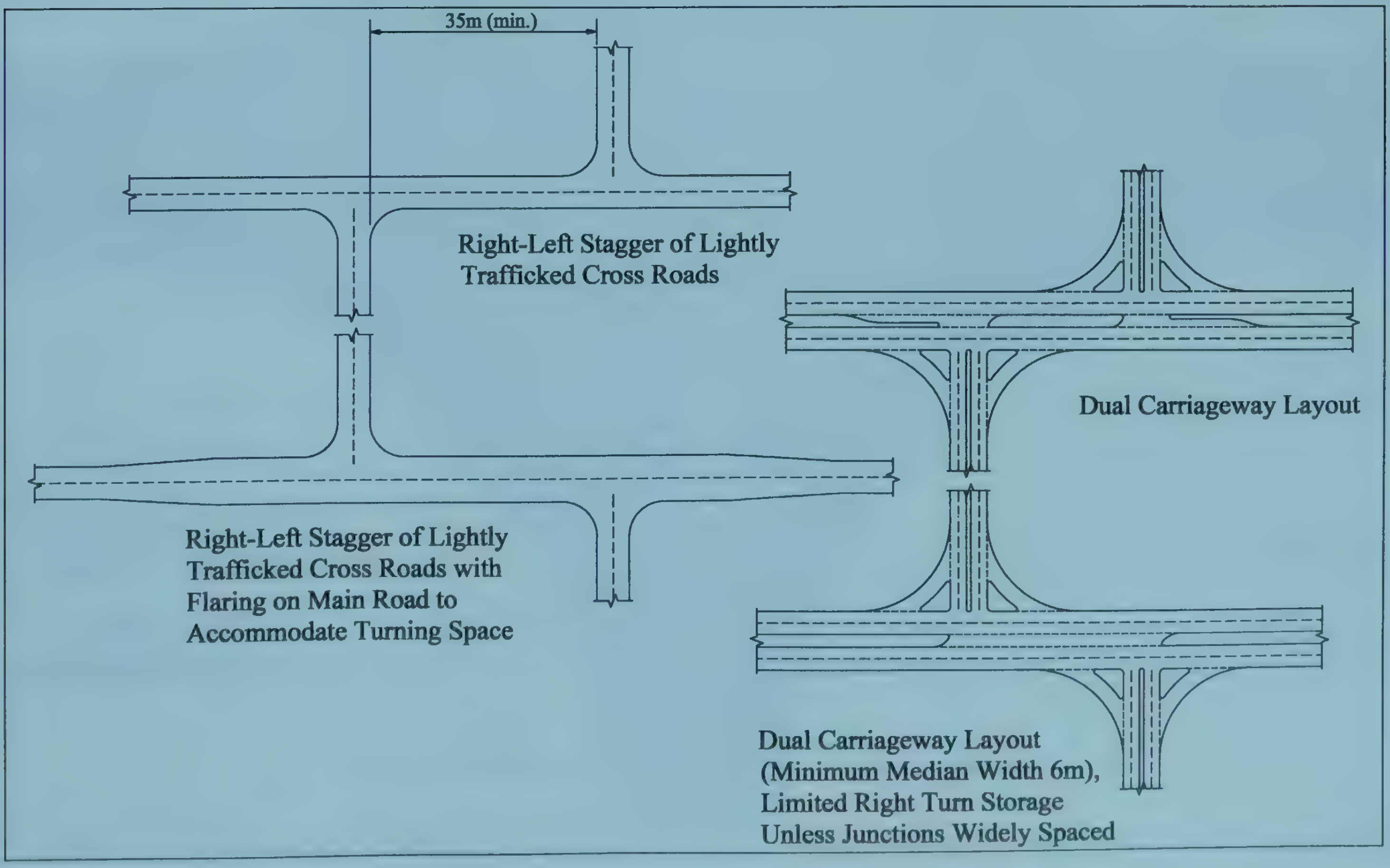

35m (min.)
Right-Left Stagger of Lightly Trafficked Cross Roads
Dual Carriageway Layout
Right-Left Stagger of Lightly Trafficked Cross Roads with Flaring on Main Road to Accommodate Turning Space
Dual Carriageway Layout (Minimum Median Width 6m), Limited Right Turn Storage Unless Junctions Widely Spaced

Fig. 4.5 Staggering of Intersections

iii) Safety: A systematic record of accidents should be kept and expert inputs obtained in designing the right type of intersection.

iv) Alignment and Profile: Special attention be paid to alignment and profile for roads in hill towns. Grade in excess of 3 percent be avoided. Change in cross slope should be gradual.

Curve radii in urban situations should draw a balance between the requirements of vehicles and pedestrians. Increase in curve radii can lead to increase in crossing distance for pedestrians. For arterial streets, radii of 9m to 15m may suffice.

v) Parking should not be allowed close to intersections.

For more details, refer to IRC:SP:41

4.3 Roundabouts

A roundabout is a specialized form of at-grade intersection where vehicles from the converging arms are forced to move around a central island in one direction. They move in a regimented manner and weave out of the roundabout into their desired direction. For details, refer IRC:SP:65.

Geometric Elements: The key geometric elements of roundabout are given in **Fig. 4.6**.

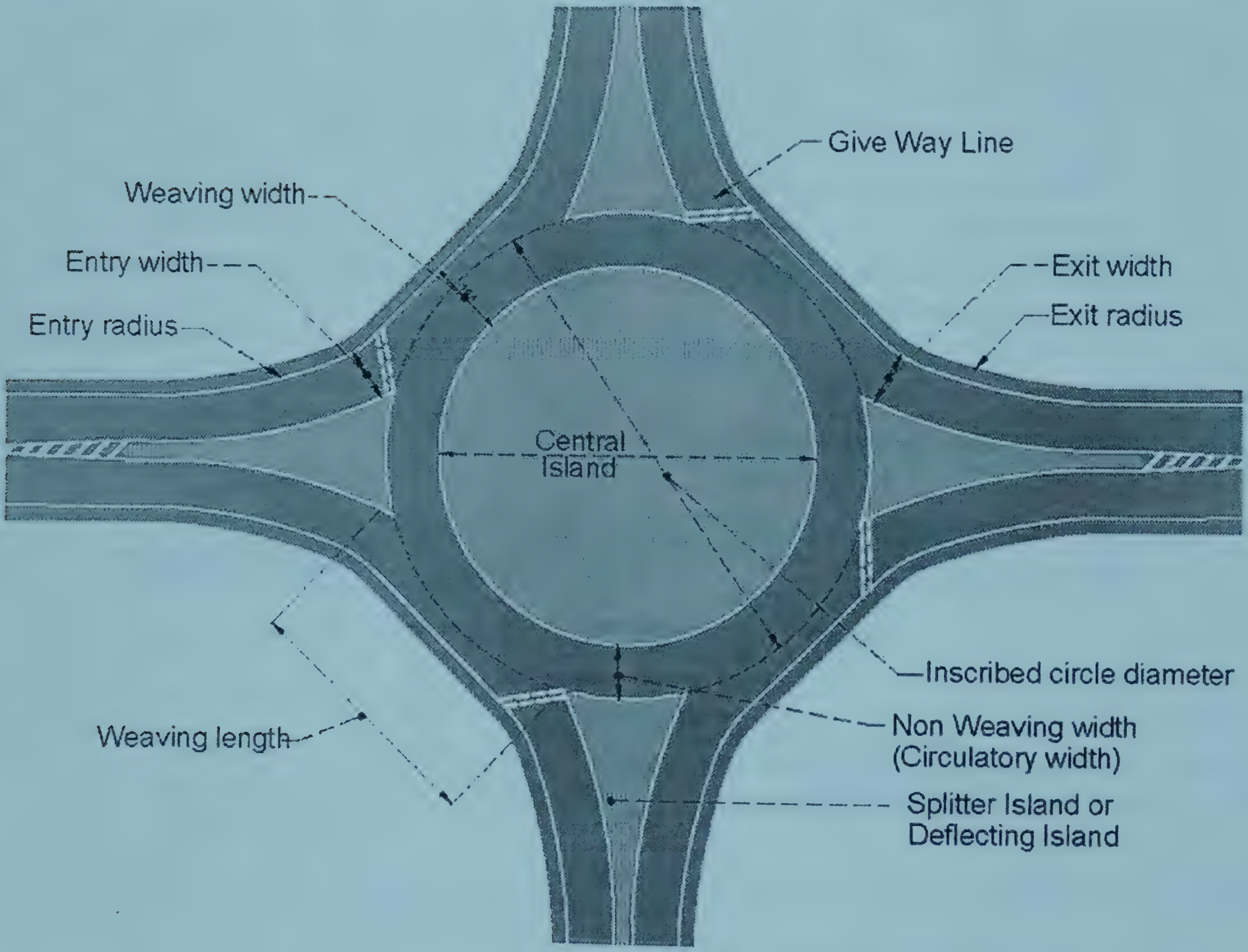

Give Way Line
Weaving width
Entry width
Exit width
Entry radius
Exit radius
Central Island
Inscribed circle diameter
Weaving length
Non Weaving width (Circulatory width)
Splitter Island or Deflecting Island

Fig. 4.6 Geometric Elements of Roundabout

A few typical single lane and multilane roundabouts are given in **Figs. 4.7** and **4.8**.

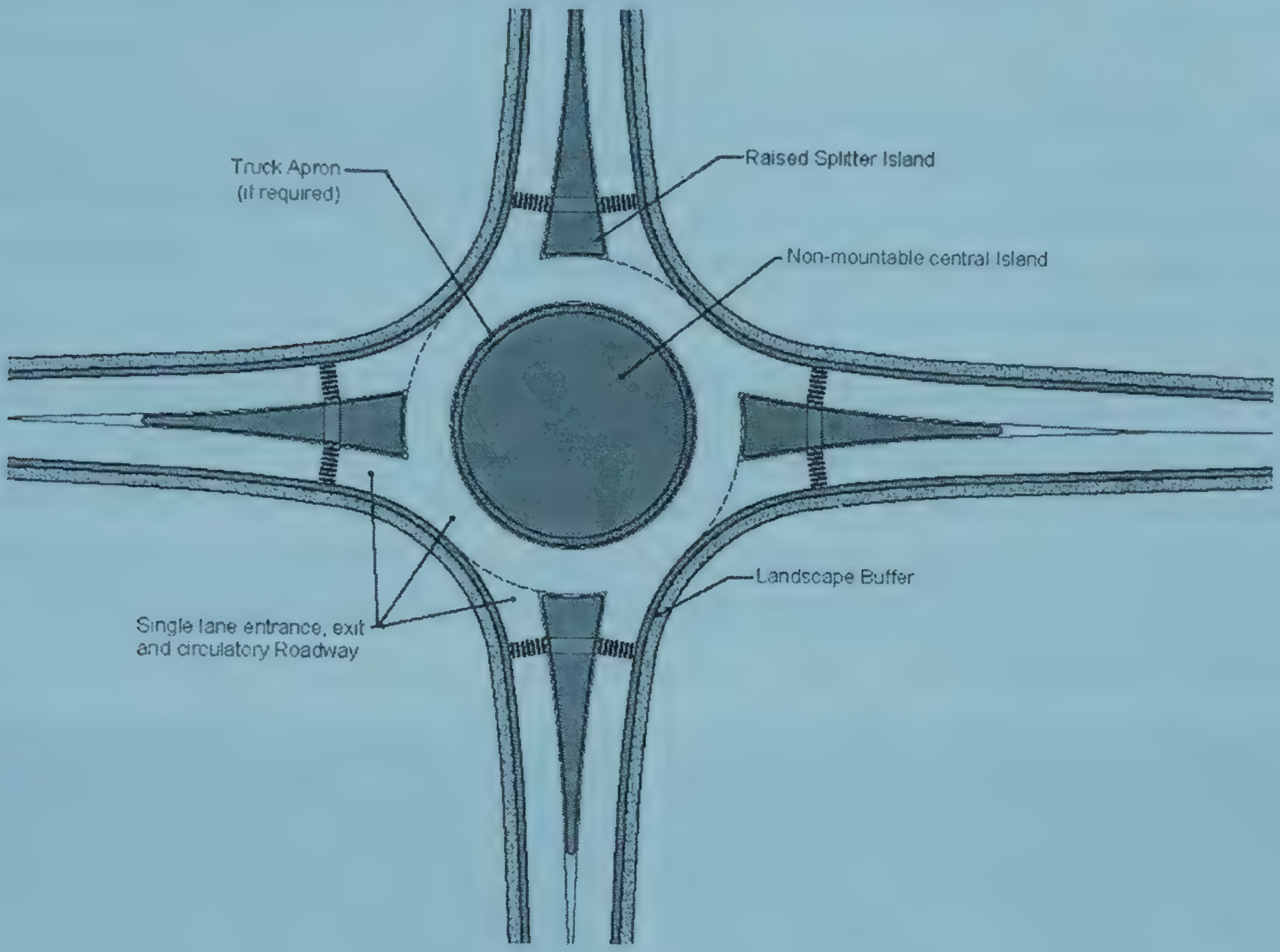

Truck Apron (if required)
Raised Splitter Island
Non-mountable central Island
Landscape Buffer
Single lane entrance, exit and circulatory Roadway

Fig. 4.7 Typical Single Lane Roundabout

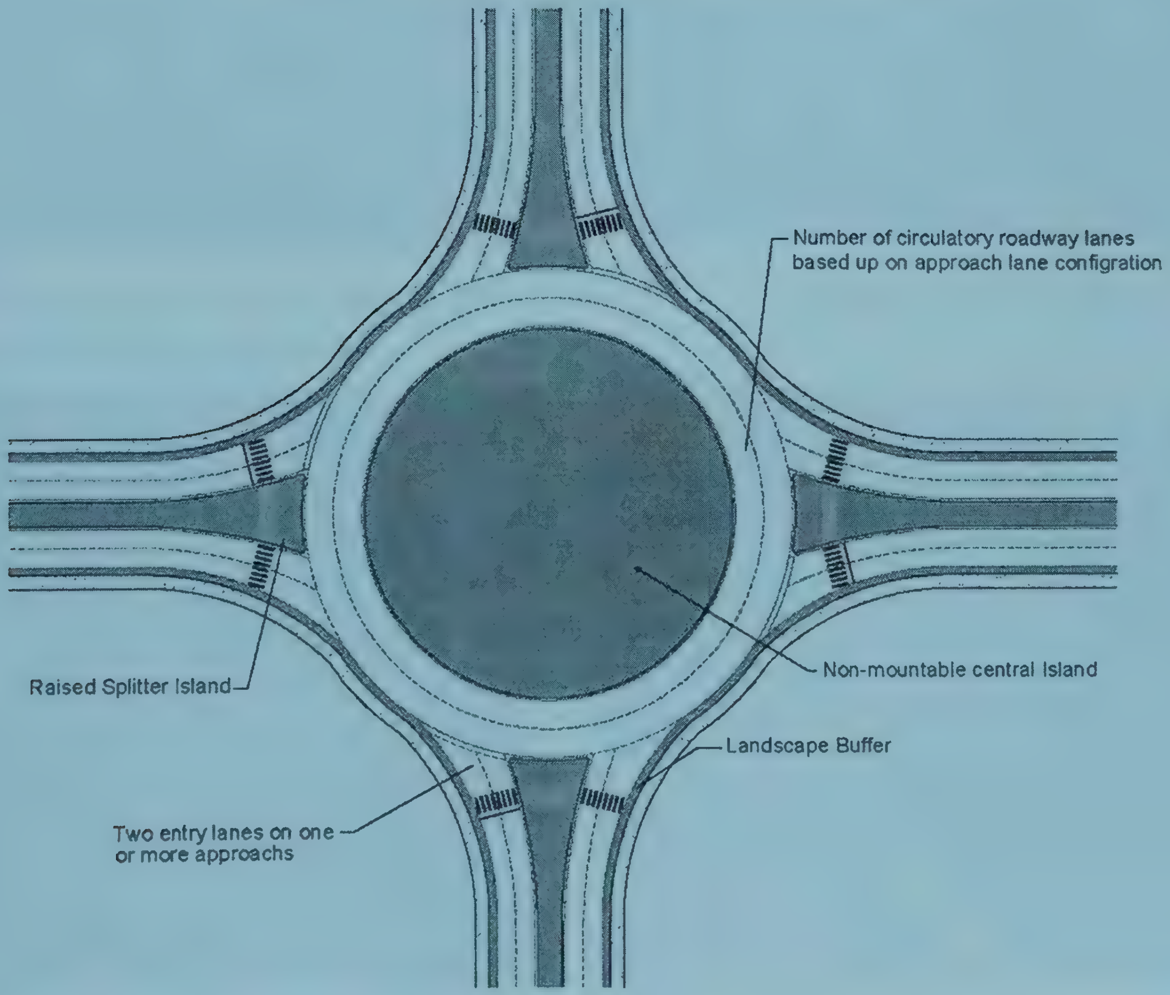

Number of circulatory roadway lanes based up on approach lane configration
Raised Splitter Island
Non-mountable central Island
Landscape Buffer
Two entry lanes on one or more approachs

Fig. 4.8 Typical Multi-Lane Roundabout

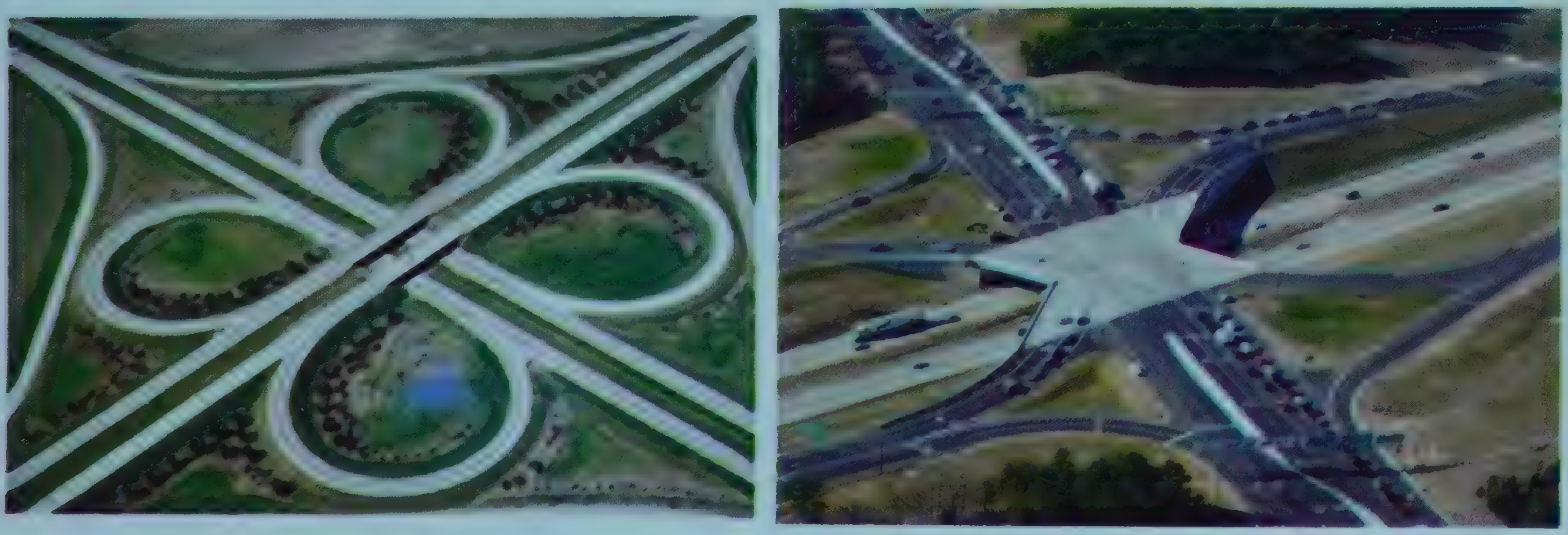
Design: Expert advice should be sought in design of roundabouts so that they ensure safe and smooth movement of traffic. For more details, refer IRC:SP:65.

4.4 Interchanges

4.4.1 *Introduction*

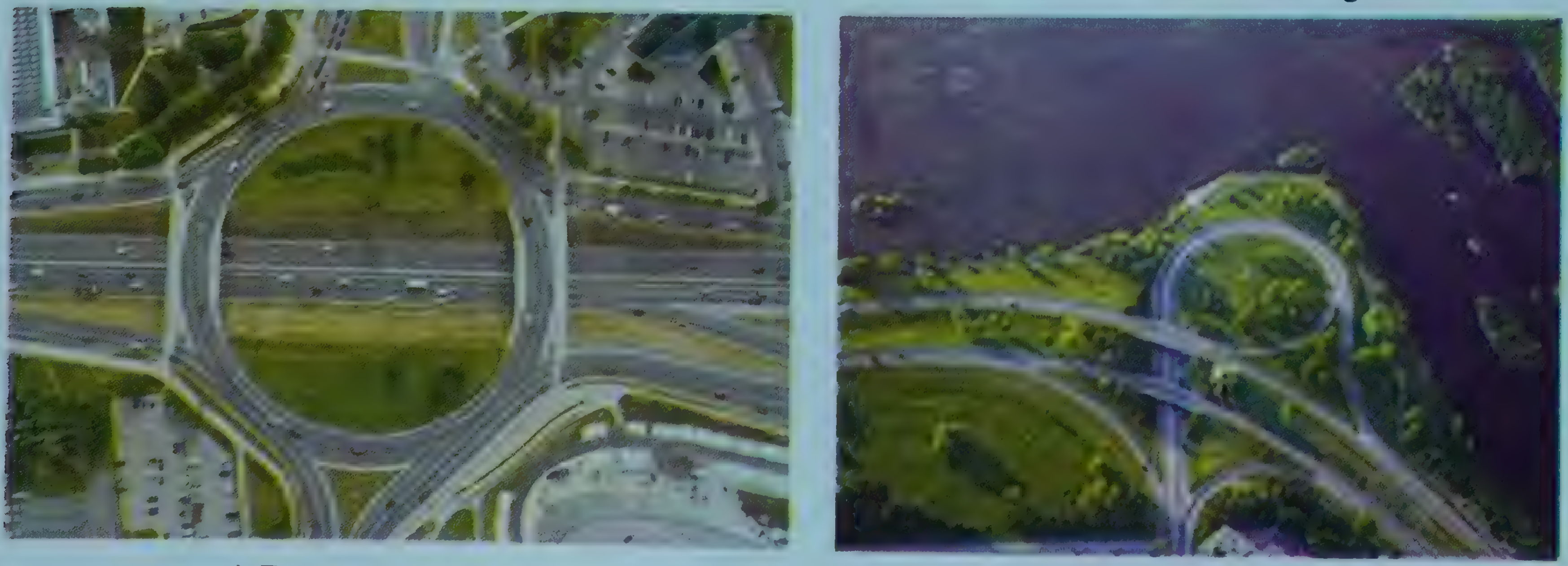
Grade separated intersection or road interchange is fundamentally explained as a crossing of two or more roadways at different levels to meet its prerequisite of uninterrupted movement of vehicles. Interchanges are predominantly used to carry fast moving motorized traffic to decongest an at-grade intersection or to segregate the conflicting movements of an intersection, thus improving its operational efficiency.

Type of interchange, shape and pattern of the interchange ramps, planning considerations, geometric design factors, composition of traffic, capacity, speed, right of way, cost, safety, topography, environmental factors etc. varies from site to site. Interchanges, therefore, are necessarily designed individually in light of these considerations. Unless and otherwise specifically mentioned, general principles of facility design are to be followed as per the standard practice. For details, refer IRC:92.



a) Cloverleaf Interchange

b) Single Point Urban or Single Point Diamond Interchange



c) Rotary Interchange

d) Trumpet Interchange

Figs. 4.9 Diverse Types of Interchanges

4.4.2 *Typology of Interchange*

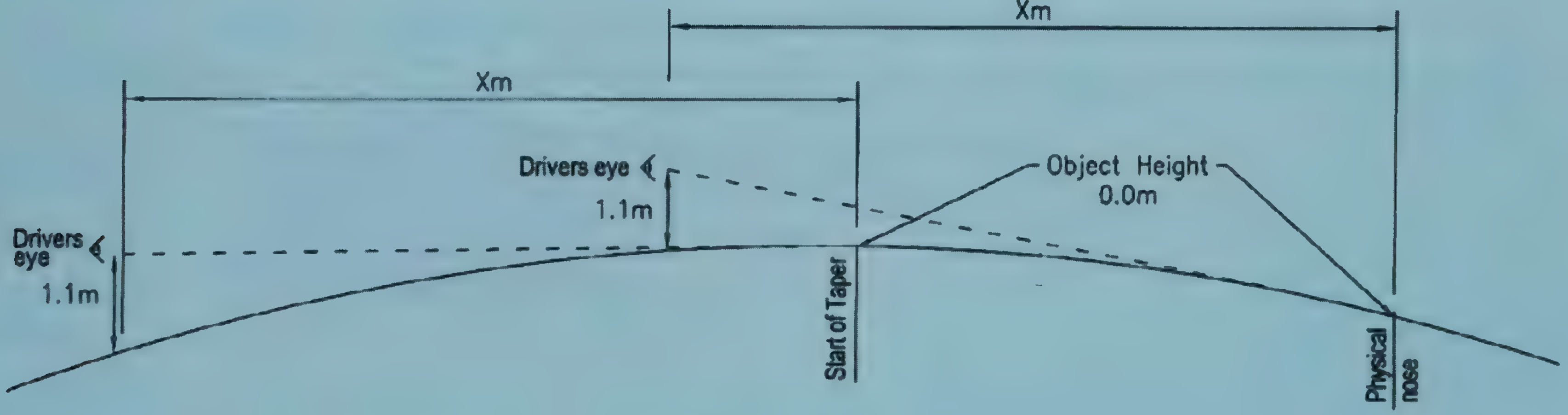
Based upon partial and complete grade separation along with number of arms, interchanges can also be classified as –

1. 3-arm Partially Grade Separated
2. 3-arm Totally Grade Separated
3. 4-arm Partially Grade Separated
4. 4-arm Totally Grade Separated

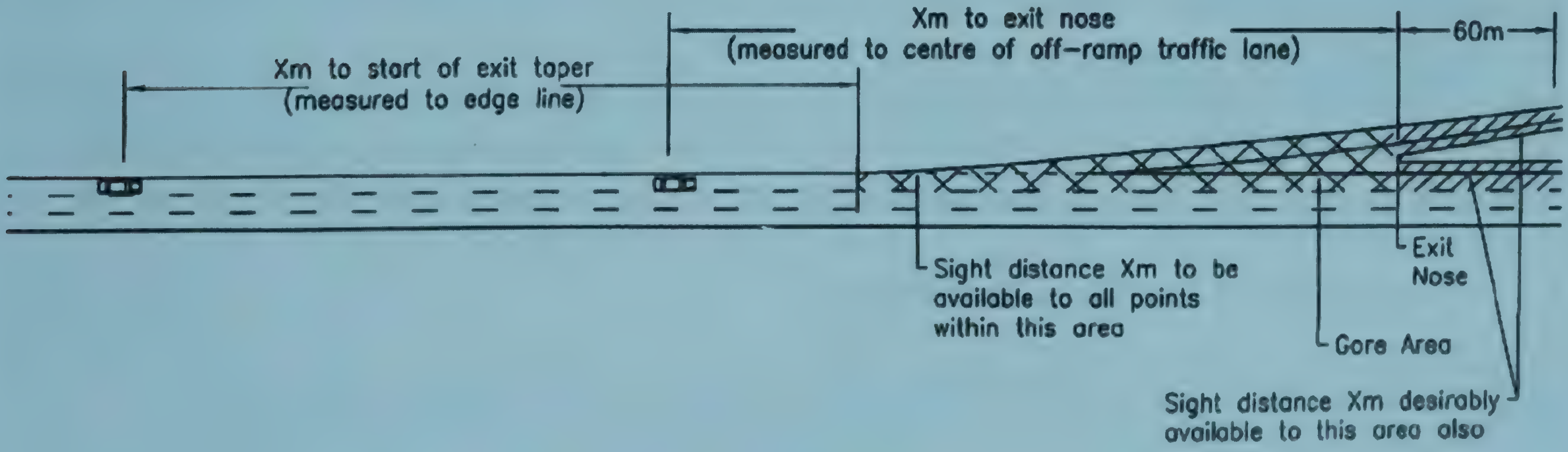
Refer IRC:92 for more details and to view the typical layouts of interchanges.

4.4.3 *Planning and Design considerations for Interchange*

The planning considerations for an interchange include: lane requirement, interchange spacing, access control, land use and warrants. The geometric considerations include: design vehicles, design speed, horizontal curvature, sight distance, ramp details, grade and profiles, ramp terminals, lateral clearance, vertical clearance, super elevation on ramps etc. Detail guidelines for the above-mentioned parameters are given in IRC:92. **Figs. 4.10(a)** and **(b)** show the sight distance requirements at exit ramps. Typical designs for entrance and exit terminal provided with acceleration and deceleration lane respectively are shown in **Fig. 4.11**.


Xm
Xm
Drivers eye
1.1m
Object Height
0.0m
Drivers eye
1.1m
Start of Taper
Physical nose

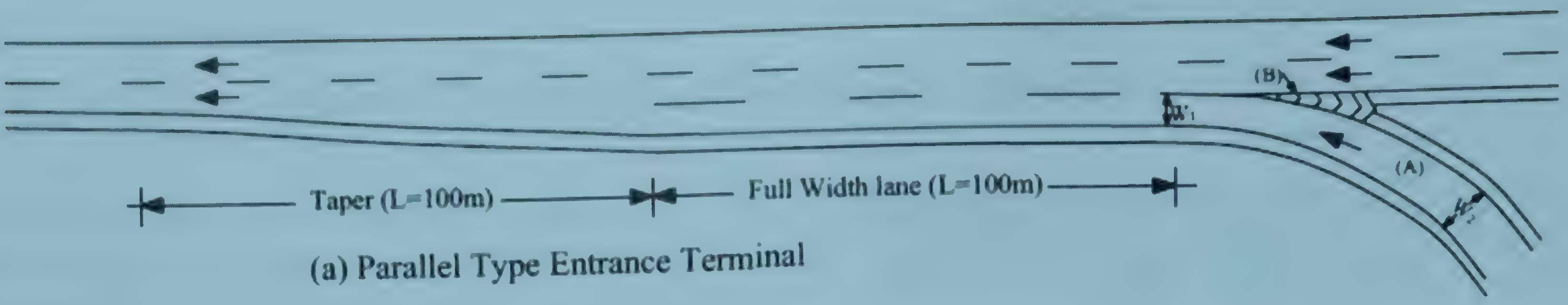
(a) Elevation


Xm to start of exit taper
(measured to edge line)
Xm to exit nose
(measured to centre of off–ramp traffic lane)
60m
Sight distance Xm to be available to all points within this area
Exit Nose
Gore Area
Sight distance Xm desirably available to this area also

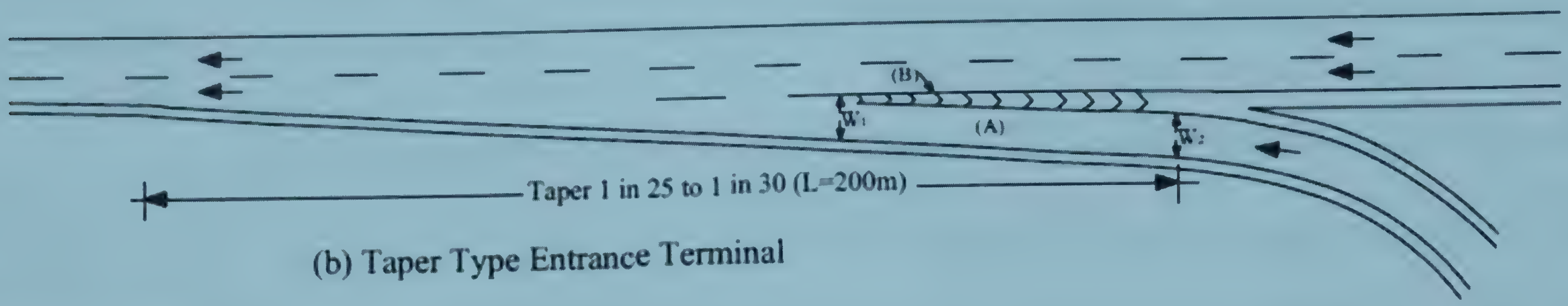
(b) Plan

Fig. 4.10 Sight Distance Requirements at Exit Ramps

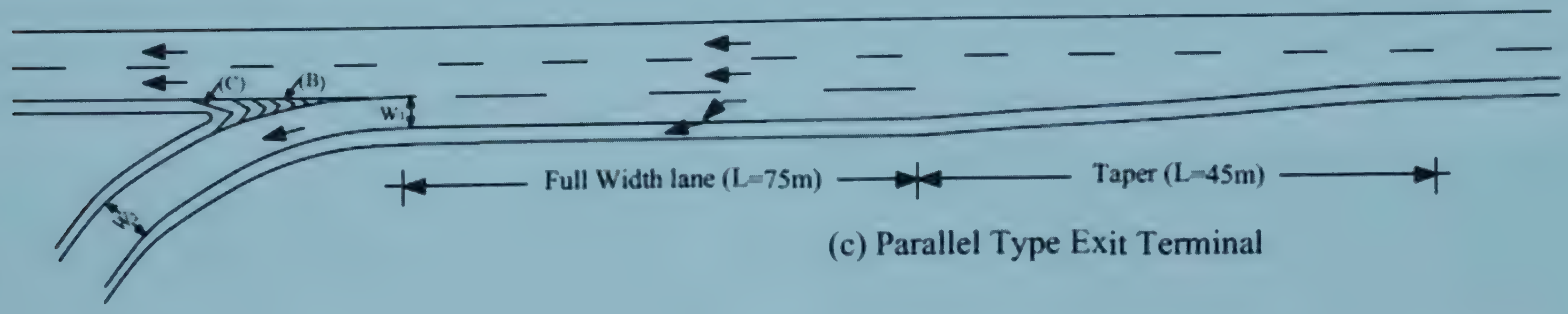
Notes: In **Figs. 4.10(a)** and **(b)**, the distance X m is based on a minimum of 10 seconds of travel time.


(B)
W₁
(A)
W₂
Taper (L=100m)
Full Width lane (L=100m)

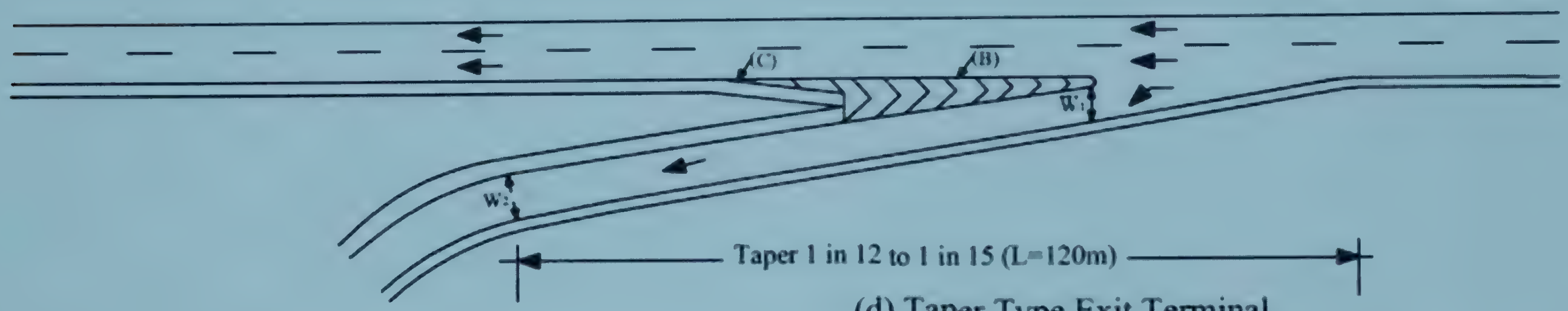
(a) Parallel Type Entrance Terminal


(B)
W₁
(A)
W₂
Taper 1 in 25 to 1 in 30 (L=200m)

(b) Taper Type Entrance Terminal


(C)
(B)
W₁
W₂
Full Width lane (L=75m)
Taper (L=45m)

(c) Parallel Type Exit Terminal


(C)
(B)
W₁
W₂
Taper 1 in 12 to 1 in 15 (L=120m)

(d) Taper Type Exit Terminal

Fig. 4.11 Typical Designs for Entry and Exit Terminals

Notes:

1. At locations marked (A) funnel entrance is provided by reducing width of ramp (W_2) to width of lane (W_1)
2. The nose area marked (B) should be paved and provided with markings in white paint as indicated
3. At locations marked (C), the through lane should be tapered (1 in 10) for a distance of 20m

The road markings may be provided as per IRC:35 “Code of Practice for Road Markings”.

4.4.4 *Interchange Selection Parameters*

The decision to provide a grade-separated intersection should be made based on careful consideration of a number of factors. Traffic passing through an interchange should be afforded the same degree of utility and safety as that given on the approaching roads. The design speed, alignment, profile, and cross section in the intersection area, therefore, should be consistent with those on the approaching roads, even though this may be difficult to attain. The presence of the structure itself is somewhat of an obstruction, which should not be augmented by inconsistent designs that might encourage undesirable driver behaviour. Preferably, the geometric design at the highway grade separation should be better than that for the approaching roads to counter balance any possible sense of restriction caused by abutments, piers, kerbs and rails.

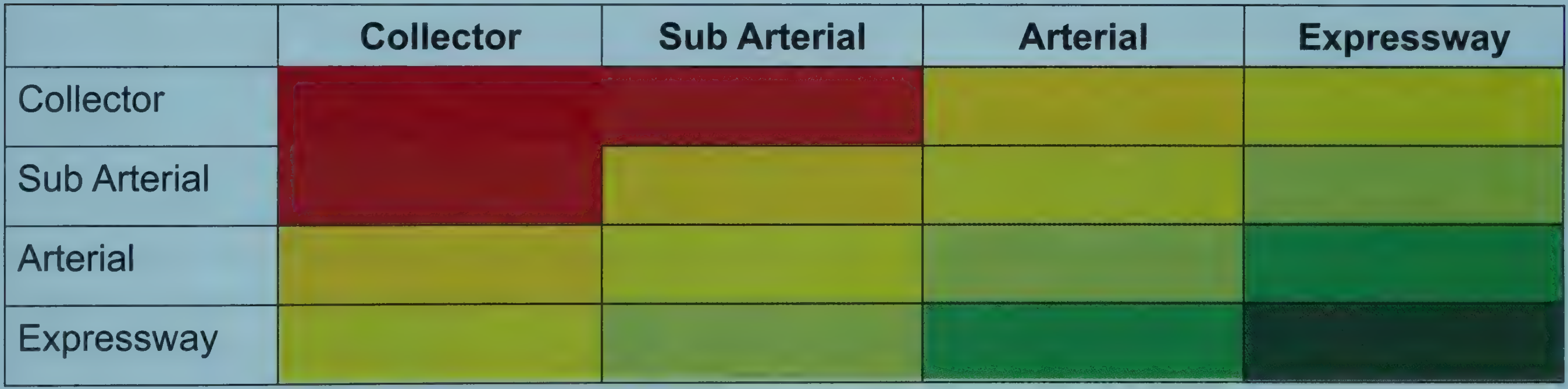
A grade separation without interchange ramps may be provided to avoid having interchanges so close to each other that traffic signage and operation would be difficult. Such a strategy eliminates interference with large major road interchanges and increases safety and mobility by concentrating turning traffic at a few points where it is feasible to provide adequate ramp systems. On the other hand, undue concentration of turning movements at one location should be avoided where it would be better to have additional interchanges.

Lacking a suitable relocation plan for the crossroad, a grade separator without ramps may be provided to maintain connectivity of low volume roads. Users desiring to access one facility from the other are required to use other existing routes.

Many times partial interchanges are constructed initially because the traffic volumes do not support a full interchange or the required right-of-way is not available when the interchange is first constructed. As time passes, however, the need for a complete interchange may develop and the right-of-way may be acquired as per design of layout.

Matrix given in **Table 4.1** can act as guiding principle for assessing the feasibility of complete interchanges along an urban corridor.

Table 4.1 Guiding Principle for assessing Feasibility of Interchange



	Collector	Sub Arterial	Arterial	Expressway
Collector	🟥	🟥	🟧	🟨
Sub Arterial	🟥	🟧	🟨	🟩
Arterial	🟧	🟨	🟩	🟩
Expressway	🟨	🟩	🟩	⬛

Selection of the most appropriate type of interchange for the prevailing conditions is an important step in design. The specific form or type of interchange will depend on the physical conditions of the site such as topography, available right-of-way, land-use and developments alongside the intersecting roads, expected volumes of through and turning traffic including their composition, orientation of the intersecting roads, etc.

4.4.5 *Study of Physical Conditions*

The site studies should include:

i) Topography – this will bring out the roadway that can be made to flyover or run in a subway as also the pattern and possible location of the ramps for maximum economy.

ii) Location, alignment and design features of the intersecting roads – this will help to identify or distinguish the major road where free flow type ramp terminals may be necessary. On a road with frequent at-grade intersections, the ramp terminals should also be at-grade. Similarly, terminals on roads carrying more than 10 per cent slow traffic (i.e. carts, bicycles, etc.) should be at grade.

iii) Roadside developments – the design should be conducive to provide access to roadside properties and connection to existing access roads. This may call for construction of frontage road or collector roads with connection to the arterial road at appropriate points.

iv) Practicability of maintaining traffic during construction – this is important where the intersecting roads are existing roads. When the fly-over structure is under construction, it should be possible to provide for at-grade connections to all traffic movements.

v) Flexibility for future adjustment and stage development – this should include a study of the design vis-à-vis the planned developments in the adjoining area, augmentation of services and other improvements.

4.4.6 *Safety Considerations for Non-Motorized Vehicles (NMV)*

Integration of bicycles into multi-modal transport chains, particularly with public transport modes, contributes to a more efficient and environmentally sustainable transport system. A well-integrated bus-bike system increases bus ridership levels. The common safety issues for an NMT network are: 1. Insufficient Lighting; 2. Lengthy crossing distances; 3. Discontinuous facilities; 4. Unmarked crossings; 5. Free-flowing entry and exit ramps; 6. Poor sight distance.

The factors of safety considerations of an NMV network in an interchange are explained in IRC:92 along with typical design challenges, illumination, noise pollution barriers and landscaping at interchanges.

4.4.7 *Design*

Expert advice should be sought in design of interchanges.

CHAPTER 5

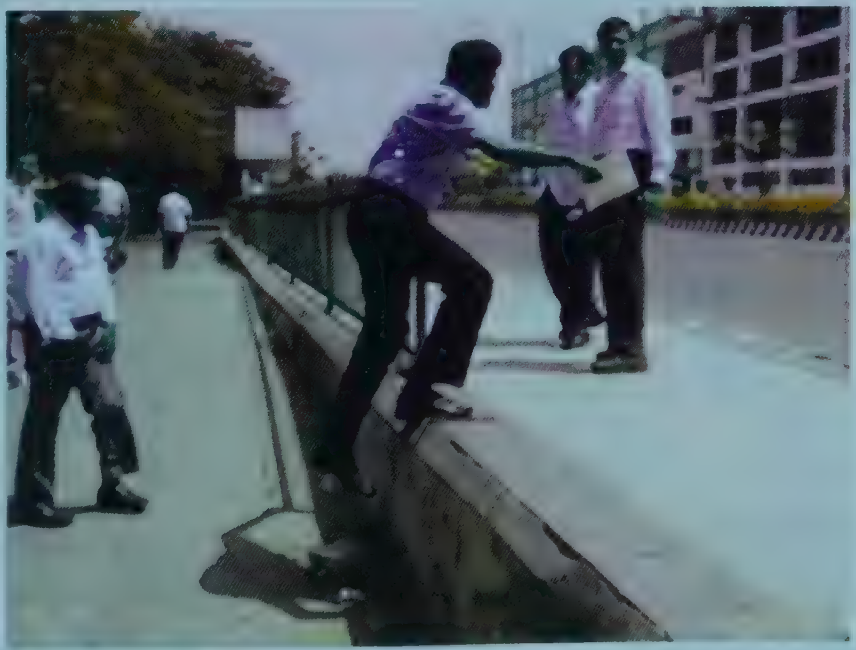
PEDESTRIAN FACILITIES

A complete trip chain (connectivity and seamless journey) starts from the point of origin to the walk/commute, cycle and/or wait for transport, boarding, travel and alighting followed by the walk/commute to the final destination. Each trip chain must ensure pedestrian safety for all including persons with and without disabilities. Any break in the trip chain results in lack of access and independent mobility. Inaccessible links require taking an indirect route, increasing travel times, fatigue, uncertainty and potential modal conflicts. The goal must be for people to have access to all vehicles and the full service area, as well as the pedestrian environment (WHO, 2011). This chapter draws heavily from IRC:103 "Guidelines for Pedestrian Facilities". Objectives in creating pedestrian facilities are to:

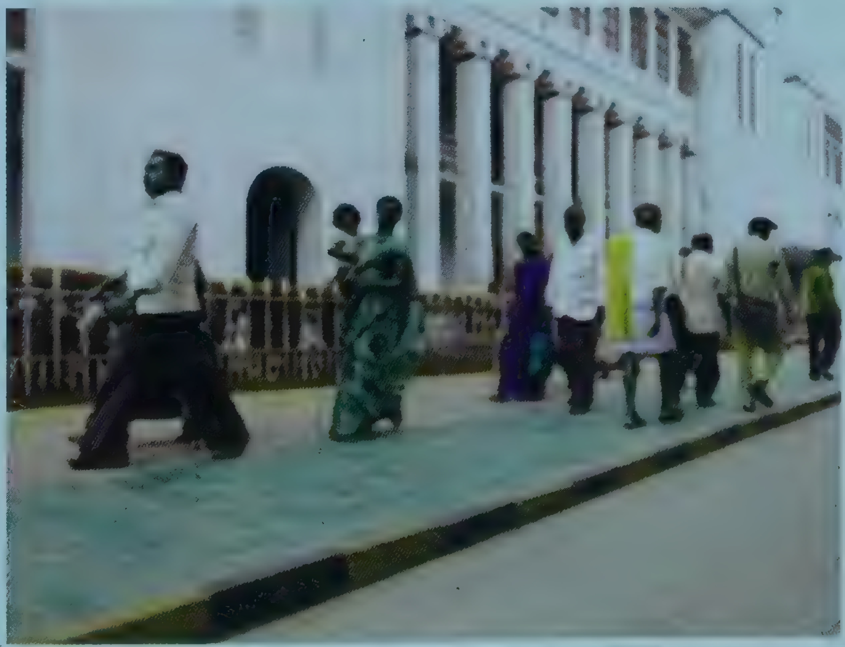
- Ensure safe and independent commute between places of origin and destination, including first and last mile connectivity;
- Provide convenient, quick access and exit and usage of all areas;
- Implement inclusive design and achieve social inclusion (including persons with reduced mobility and persons with disabilities); and
- Increase energy-efficiency in transport by improving the trip chain of all citizens.

5.1 Footpaths

Pedestrian footpaths are defined as any area primarily used by 'all' pedestrians. They can be adjacent to roadways or away from the road. Footpaths should be regarded as a transportation system which is connected and continuous, just like roadways and railways. They should be provided consistently between all major attractions, trip generators, and other locations where people walk. In order to be effective, the side-walks should be provided on both sides of the road and above the level of the carriageway separated by kerbs. Height of the kerb at the edge should, however, not exceed the height of a standard public step riser i.e. 150 mm, as this might otherwise detract pedestrian from getting on the side-walks. **Figs. 5.1** and **5.2**.



✗ **Fig. 5.1 Excessive Height of Kerb makes Footpaths hard to use, and many Pedestrians prefer to walk in the Carriageway**



✓ **Fig. 5.2 Footpaths with a Height of Kerb no more than 150 mm are more likely to be used**

The footpaths should be continuous as well as segregated unless at stretches where narrow right of way rules out the possibility of segregated paths. At such locations, visual continuity should be maintained using texture and pavement markings. Paths should be shaded and space for facilities such as service providers (hawkers), benches, street light poles etc..

Zoning System

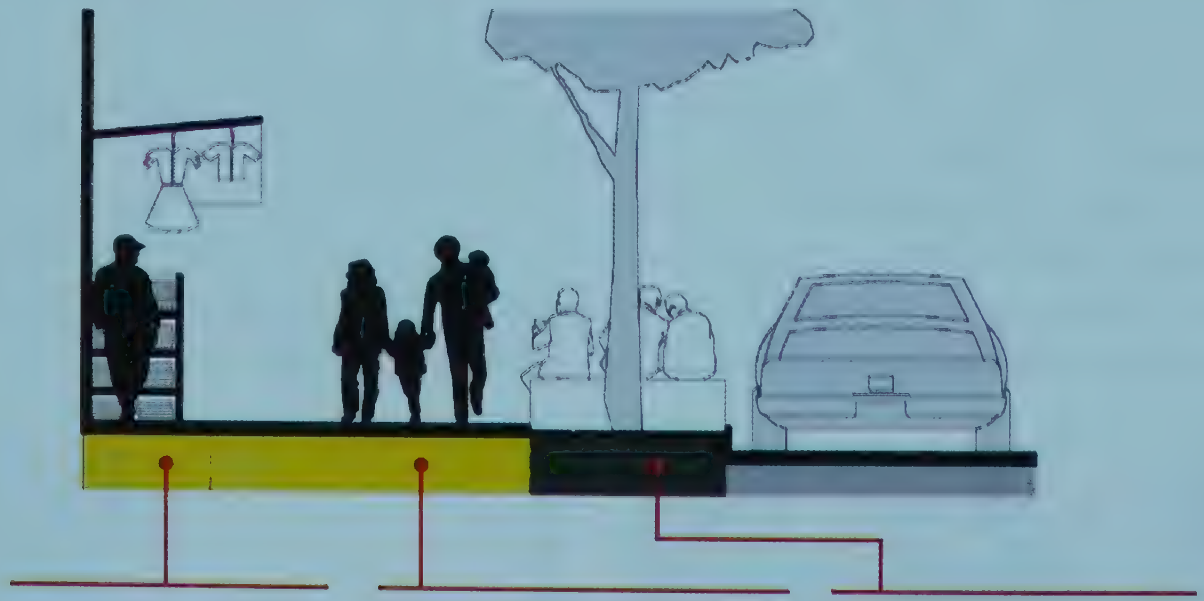
Comfort, continuity, and safety are the governing criteria for the design and construction of pedestrian facilities. For this reason, the footpaths are divided into three main zones: the frontage zone (also known as "dead width"), the pedestrian zone, and the furniture or multi-functional zone. See **Fig. 5.3**. Each of these zones plays an important role in a well-functioning footpath.

- **Frontage zone**

  The frontage zone can vary from a minimum width of 0.5m along a compound wall to 1.0 m in commercial zones.
- **Walking Zone**

  The walking zone provides continuous clear space for walking. The clear width must be at least 1.8m and 2.2m clear height in order to accommodate two wheelchair users at the same time and must be entirely free of obstructions.
- **Furniture zone**

  Manholes, trees, benches, utility boxes and other potential obstructions should be placed outside the path of travel along a continuous line.



Frontage zone. The frontage zone can vary from a minimum width of 0.5 m along a compound wall to 1.0 m in commercial zones (IRC:103-2012, 6.1.5.3).

Pedestrian zone. The pedestrian zone provides continuous clear space for walking. The clear width must be at least 1.8 m in order to accommodate two wheelchair users at the same time (IRC:103-2012, 6.1.3) and must be entirely free of obstructions (IRC:103-2012, 6.1.10.2).

Furniture zone. Manholes, trees, benches, utility boxes and other potential obstructions should be placed outside the path of travel along a continuous line (IRC:103-2012, 6.1.10.2, 6.11.4).

Fig. 5.3 Footpath Zones

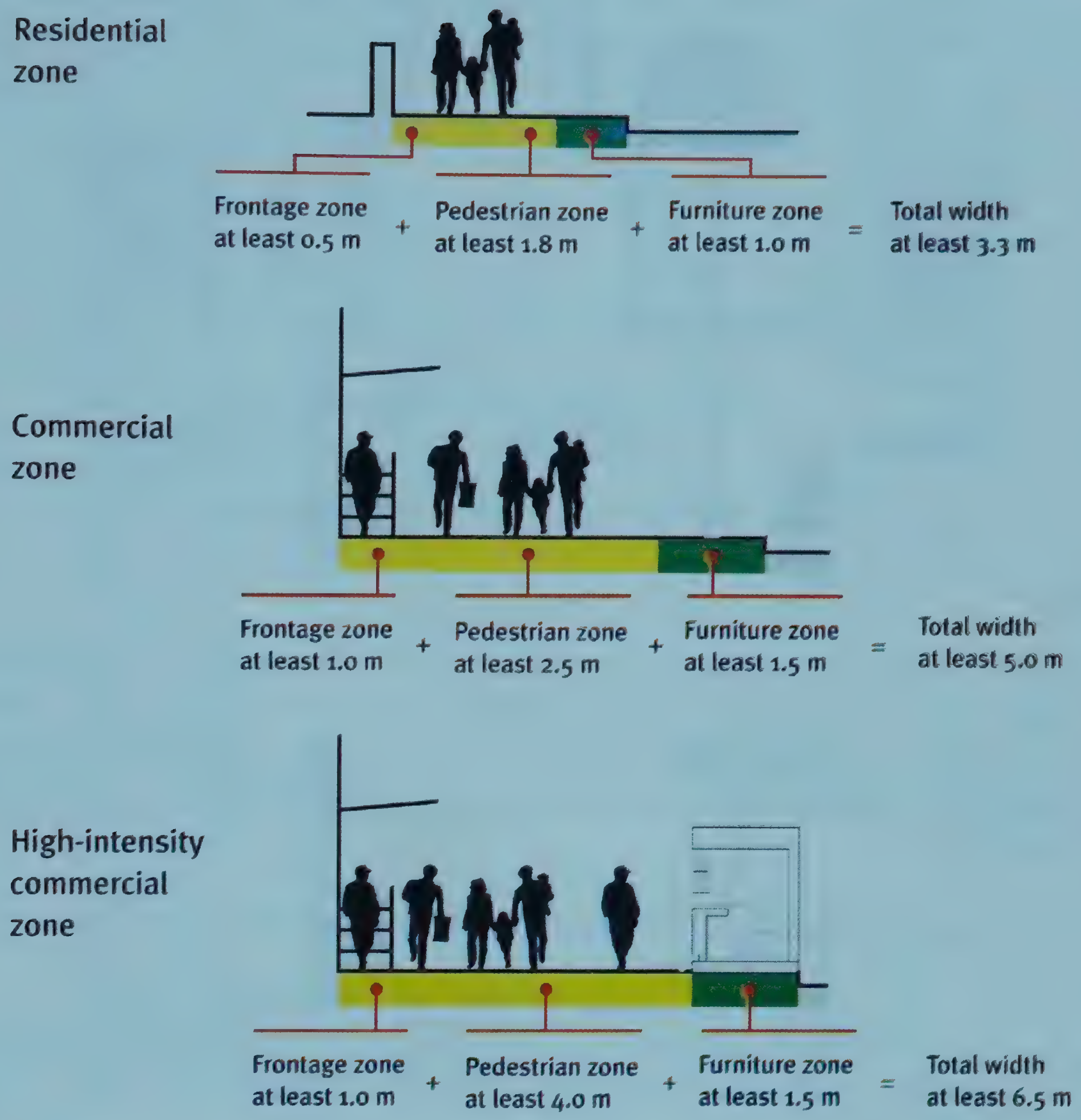

Residential zone
Frontage zone at least 0.5 m
+
Pedestrian zone at least 1.8 m
+
Furniture zone at least 1.0 m
=
Total width at least 3.3 m
Commercial zone
Frontage zone at least 1.0 m
+
Pedestrian zone at least 2.5 m
+
Furniture zone at least 1.5 m
=
Total width at least 5.0 m
High-intensity commercial zone
Frontage zone at least 1.0 m
+
Pedestrian zone at least 4.0 m
+
Furniture zone at least 1.5 m
=
Total width at least 6.5 m

Fig. 5.4 Footpaths in Residential and Commercial Zones

Source: Footpath design: A guide to creating footpaths that are safe, comfortable, and easy to use (ITDP)

Clear Height

A clear height of 2.2m is required for the entire width of the footpath walking zone. No tree branches, trees, utility poles, electric/water/telecom boxes or signage should be placed within the clear height and width of the Walking Zone.

Width

The width of a footpath is fundamental to the effective functioning of the pedestrian system. The width of side-walks depends upon the expected pedestrian flows and could be fixed with the help of guidelines given in **Table 5.1**. The minimum width of a clear unobstructed pathway should be 1800mm in roads of right of way of 9m and above. This allows two wheelchairs to pass each other comfortably (**Fig. 5.5**). The full width of footpath should be maintained consistently, even behind bus shelters and in front of shops.

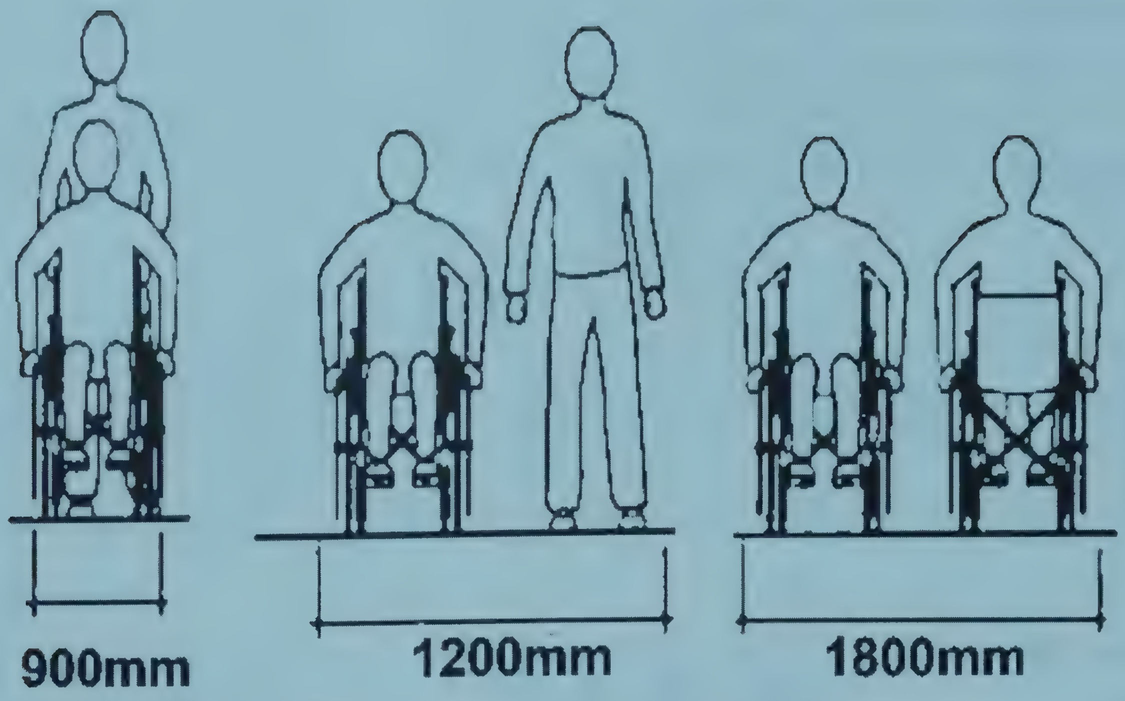


Fig. 5.5 Minimum Width of a Clear Footpath

Level of Service

Footpaths should normally be designed for a Level of Service B, thereby providing wide pedestrian facilities for pleasant and comfortable walking. Under resource constraint Level of Service C can be adopted for deciding width of footpath (**Table 5.1**). The width of the footpaths depends upon the expected pedestrian traffic and land use and may be fixed with the help of guidelines given in **Tables 5.1** and **5.2**.

Table 5.1 Capacity of Footpath (Uninterrupted Walking Zone)

Width (meter)	**Design Flow in Number of Persons per hour**			
	In Both directions		**All in One direction**	
	LOS B	**LOS C**	**LOS B**	**LOS C**
1.8	1350	1890	2025	2835
2.0	1800	2520	2700	3780
2.5	2250	3150	3375	4725
3.0	2700	3780	4050	5670
3.5	3150	4410	4725	6615
4.0	3600	5040	5400	7560

Table 5.2 Required Width of Uninterrupted Walking Zone as per Predominant Land Uses along a Street Segment

Optimum Required Width (for all zones)	2m
Minimum obstacle free walkway width in Residential Zones	1.8m
Commercial Zones	2.50m
Shopping frontages	3.5m to 4.5m
Bus Stops	3m
High Intensity Commercial (Central Business Districts, High Streets and Retail/Market Streets)	4m

Clear Walking Zone

The minimum 1.8m x 2.2m (Ht) Walking Zone should be clear of all obstructions – both horizontally and vertically. No utility ducts, utility poles, electric, water or telecom boxes, trees, signage or any kind of obstruction should be placed within the "Walking Zone" (**Fig. 5.6**). All existing obstructions must be removed.

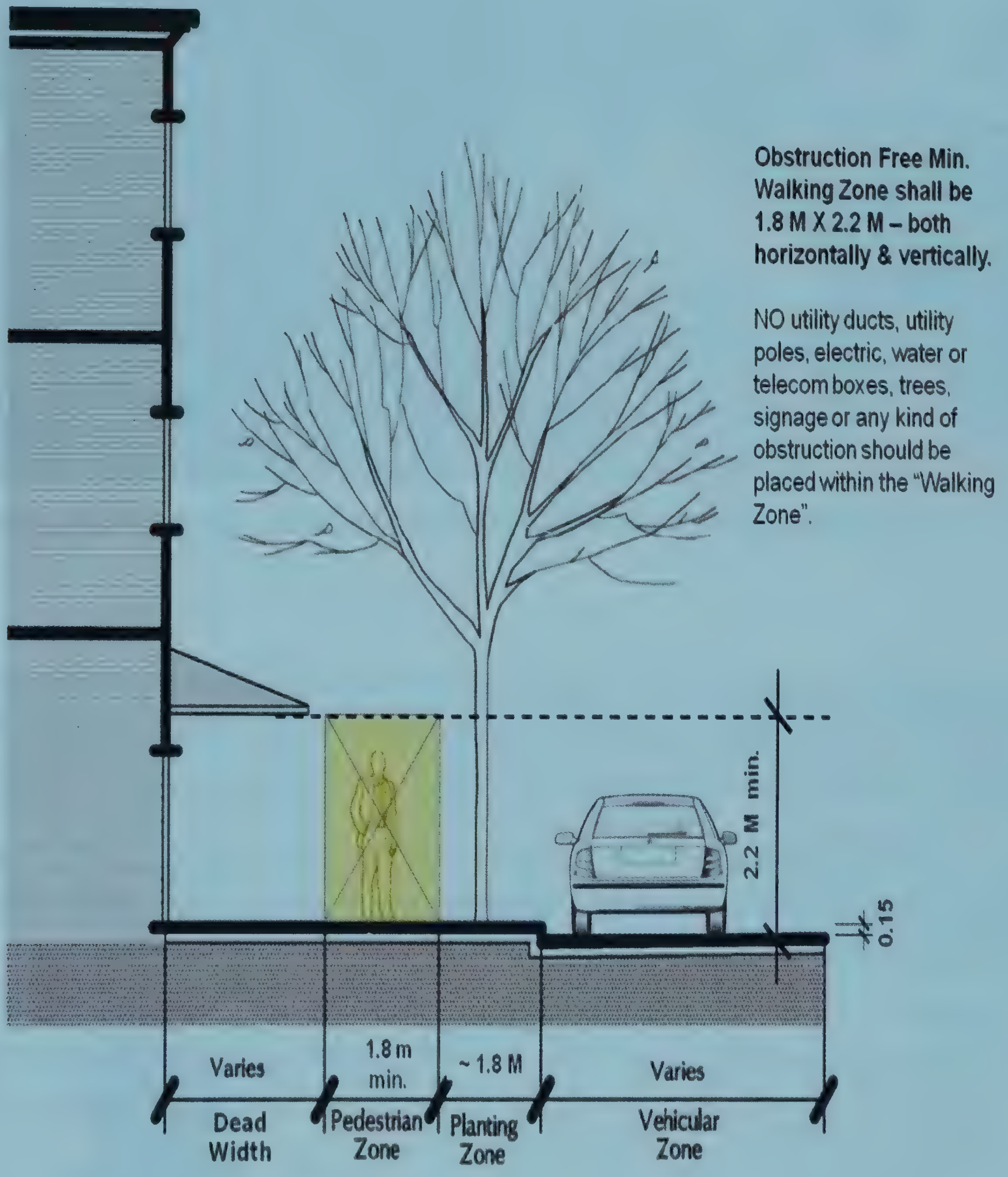

Obstruction Free Min. Walking Zone shall be 1.8 M X 2.2 M – both horizontally & vertically.
NO utility ducts, utility poles, electric, water or telecom boxes, trees, signage or any kind of obstruction should be placed within the "Walking Zone".
2.2 M min.
0.15
Varies
1.8 m min.
~ 1.8 M
Varies
Dead Width
Pedestrian Zone
Planting Zone
Vehicular Zone

Fig. 5.6 Pedestrian Zone : Clear Walking Zone is separate from Furniture Zone

Surface Quality

Footpaths should have flat walking surfaces, allowing for proper drainage and preventing puddles from forming. Tactile pavers, warning and guiding pavers should be laid along the length of the footpath to assist persons with visual impairments (**Fig. 5.7**).

Firm and even paved surfaces are important to people using sticks or crutches or wheelchairs, or people walking with difficulty. The removal of obstacles like potholes, tree roots and storm water drains crossing the walkway will do much to make it safe and usable. If brick paving is used, care should be taken to lay it evenly. Where grates over storm water drains cannot be kept out of the footpath, the gratings should be aligned across the direction of travel to prevent wheelchair from falling through. The gap between paving slabs or any vertical deviation between slabs should not exceed 5mm.

Fig. 5.7 Footpaths with Levelled Surface is easy to use by Pedestrians

Kerb Ramp

Kerb should be dropped, to be flush with walk way, at a gradient no greater than 1:10 on both sides of necessary and convenient crossing points (**Fig. 5.8**). Width should not be less than 1200 mm. If width (X) is less than 1200mm, then slope of the flared side shall not exceed 1:12;

Floor tactile paving- Guiding and Warning paver shall be provided to guide persons with visual impairment so that a person with visual impairment does not accidentally walk onto the road (**Fig. 5.9**); and Finishes shall have non-slip surface with a texture traversable by a wheel chair.

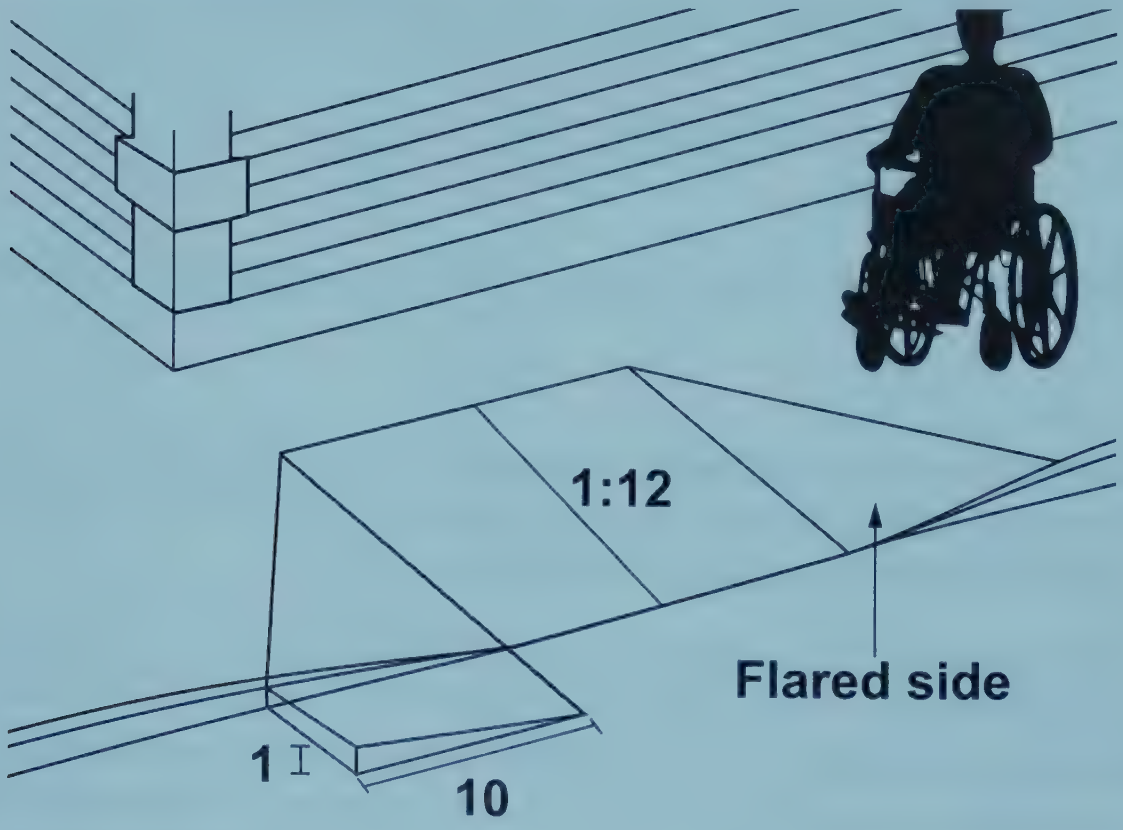


Fig. 5.8 Kerb Ramp: Gradient

Source: (Samarthyam, 2012)

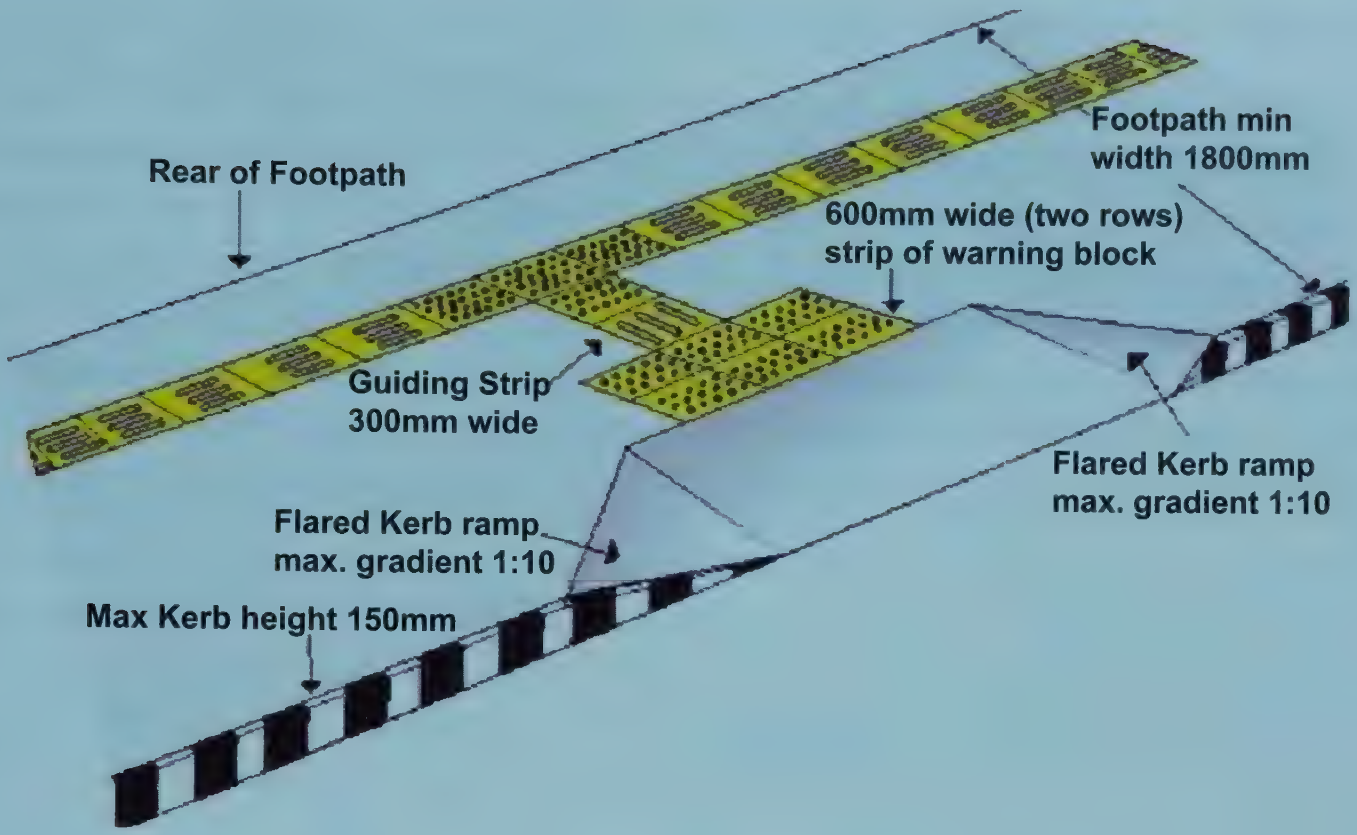

Rear of Footpath
Footpath min width 1800mm
600mm wide (two rows) strip of warning block
Guiding Strip 300mm wide
Flared Kerb ramp max. gradient 1:10
Flared Kerb ramp max. gradient 1:10
Max Kerb height 150mm

Fig. 5.9 Kerb Ramp with Tactile Pavers

Cross Falls

Cross falls should only be provided where absolutely necessary for drainage purposes and should be 1:50 maximum. If the change in cross fall is so severe that one wheel of a wheelchair or one foot of a walker leaves the ground, it may cause the wheelchair user or walker to fall. Steeper gradients tend to misdirect buggies and wheelchairs. Where falls are not adequate, silt will accumulate after rain and cause the surface to become slippery. Puddles also cause the footpath to become slippery, lead to glare in bright sunshine after other parts of the footpath have become dry and become a hazard in frosty weather. Any break in the surface, e.g. drainage channels or the gaps between boards on a walkway, should not be greater than 12mm and should cross perpendicular to the direction of movement. This will prevent walking sticks and wheels getting caught in the gaps.

Service Covers

Service covers to manhole and inspection chambers should not be positioned on footpaths, particularly at dished crossings. They can be dangerous when opened for inspection, forming a tripping hazard and reducing the clear width. Covers and gratings should be non-slip, flush/ leveled with the footpath surface, and be such that openings are not more than 10mm wide. Gratings and slot type drainage should be sited away from pedestrian flows and perpendicular to the main line of pedestrian flows so as not to trap small wheels.

Pedestrian Guardrails

Pedestrian guardrails are an important design element to prevent indiscriminate crossing and spilling over of pedestrian on to the carriageway. Their judicious use can help to ensure that pedestrians cross the streets at predetermined and safe locations. As the guard-rails would confine the movement of pedestrian to the footpath, it is obligatory that sufficient width of footpath be made available.

Bollards

Bollards are often used to stop vehicles from mounting the footpath and to keep pedestrian away from traffic. Unless positioned carefully, they can form a barrier to wheelchair users and are a particular hazard for persons with visual impairments. Where they are essential, such as to ensure clear escape routes, bollards should be identifiable by using contrasting colours by providing reflective tapes and be minimum 1000mm high. To stop use by bicycles/bikes bollards at suitable locations should be provided with clear gap/space between two bollards should be 1200mm (**Fig. 5.10**). Staggered bollards do not prohibit motorized two wheelers and make it more difficult for them to pass through, while allowing convenient access for wheelchair users and cyclists.

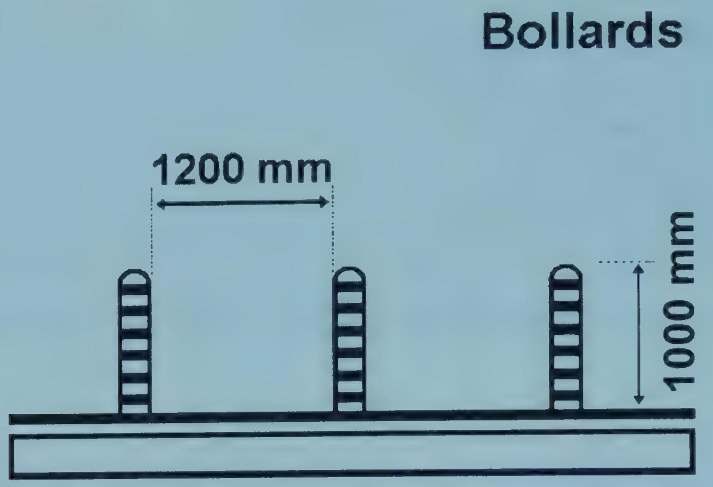
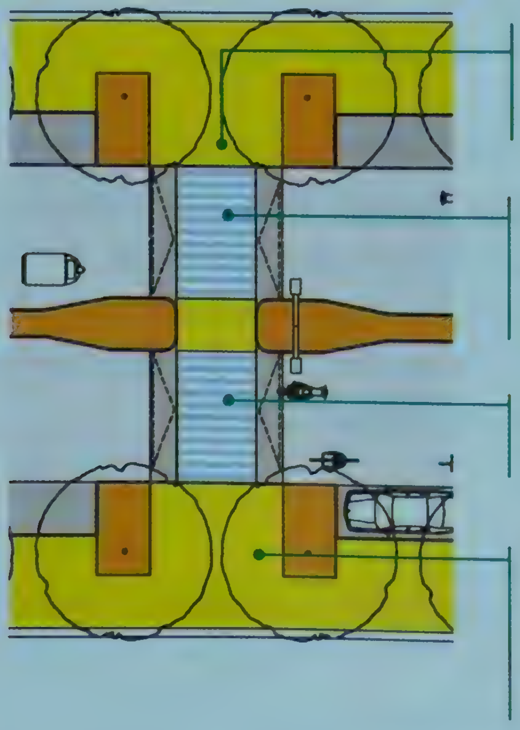


Fig. 5.10 Height and Gap between Bollards

Pedestrian Crossings

The width of the pedestrian crossing must be adequate and should generally lie within a range of 2- 4m. For divided carriageways, the crossing should provide uninterrupted movement through the median strip. In the event of the median strip being used as pedestrian refuge, adequate width of median must be provided. In case of raised medians, such portion could be suitably depressed with kerb height not exceeding 150mm. See **Fig. 5.11**.



Accessibility. Warning tiles should be placed at the edge of the footpath to warn the visually challenged about the carriageway.

Height. Crosswalks should be elevated to a level of the adjacent footpath (150 mm above the road surface) with ramps for motor vehicles with a slope of 1:5 to 1:8 (IRC:103-2012, 6.7.4.1).

Width. Crossings should be as wide as the adjacent footpath and never narrower than 3 m (IRC:103-2012, 6.7.2)

Crossing distance. Pedestrians must be given the shortest possible direct route to cross the street (IRC:103-2012, 6.7.4.1). The bulbout into the parking lane helps reduce the crossing distance.

Fig. 5.11 Raised Pedestrian Crossing

Accessibility: Warning tiles should be placed at the edge of the footpath to warn persons with visual impairments about the carriageway.

Height: Crosswalks should be elevated to a level of the adjacent footpath (150mm above the road surface) with kerb ramps for wheelchair users with a slope of 1:12 max.

Width: Crossings should be as wide as the adjacent footpath and never narrower than 2-4m.

Crossing distance: Pedestrians must be given the shortest possible direct route to cross the street. The bulbous into the parking lane helps reduce the crossing distance.

Siting of zebra crossing: A zebra crossing should not be sited within 150m of another such crossing. Provision of zebra crossings at short intervals adversely affects the overall efficiency of traffic operation in the area. For safety reasons, the zebra crossing should be somewhat set back from the carriageway line. However, the setback distance should not be so much as to cause an appreciable increase in walking distance for the pedestrian. Pedestrian guardrails may be necessary where the setback distance is appreciable or at the skew crossings.

Guardrails and lighting: Guardrails in the vicinity of zebra crossing should be of sufficient length to deter pedestrian from crossing the road at any arbitrary point along the road. Night time visibility and tactile surface of zebra crossing is of vital importance and this can be achieved through proper lighting of the intersection area and use of thermoplastic or similar 3D paint respectively.

Zebra crossing at signalized intersections: Unlike in the case of un-signalized intersections where the pedestrian uses the zebra crossings through judicious gap selection, a signalized intersection could allow exclusive time slots for movement of cross pedestrian traffic. In the case of intersections controlled by two phase signals, an “all red” phase could be inserted to ease pedestrian movements. In case of intersections controlled by three or four phase signals, zebra crossings could be utilized in such a manner that pedestrian could move across the road in a direction parallel to the movement of vehicular traffic during a particular green phase. If exclusive time slot for movement of pedestrian is not available, use of zebra crossings at such locations would also warrant judicious gap selection.

It is a good idea to install a flashing warning signal for pedestrian and left turning vehicular traffic at such intersections that permit uninterrupted infiltration to the left for vehicular traffic. Wherever pedestrian signal is provided, Stop Line should be provided to stop the vehicles and audio announcement in the signal for persons with visual impairments. The physical design features of zebra crossings at signalized intersections will be similar to those at un-signalized intersections. **Fig. 5.12** shows zebra crossings and other details for a typical four arm signalized intersection.

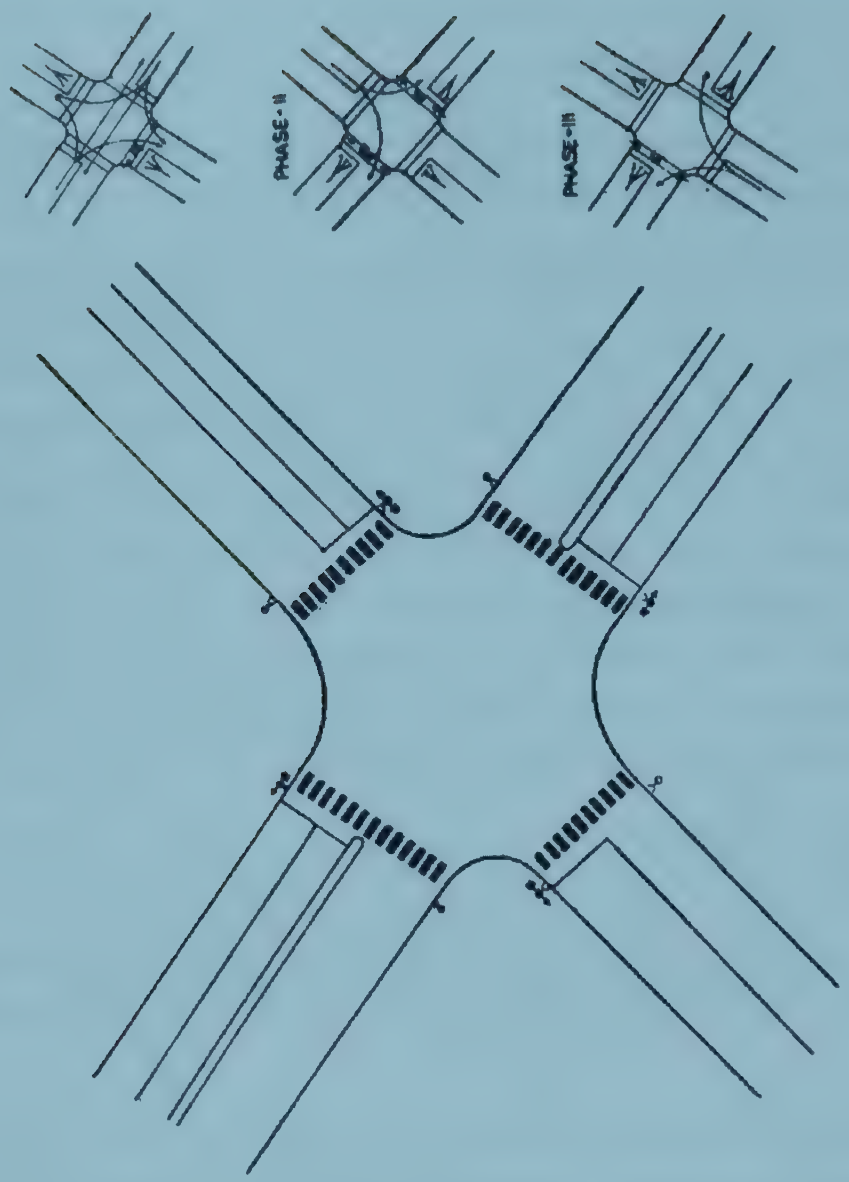


Fig. 5.12 Type of Design of Four Arm Intersection showing Zebra Crossing and Pedestrian Phases

5.2 Pedestrian Amenities

Streets must accommodate all amenities and facilities needed by pedestrians, cyclists or transit users.

Street Furniture

Street furniture comprise of a diversity of elements such as light poles, seats, kiosks, hawker zones, bins, information panels, traffic signs, parking meters and post boxes etc. These need to placed in a manner to ensure smooth movement of pedestrians. The line of furniture should allow a clear walking space of 1800mm. This allows a wheelchair user and a pedestrian to pass each other without having to give way.

Dustbin

- Dustbins – their frequent provision, cleaning and maintenance are key aspects to the cleanliness of a city. Dustbins may be provided at each bus-stop and street intersection in order to discourage people from throwing trash on the road.
- On Source Separated Dustbins – signage for “Trash type” should be made of graphic symbols – so that even illiterate people can understand how to use them.

Designated spaces for public amenities such as dustbins with segregated garbage marked both in contrast colour and pictograms **(Fig. 5.13)**.

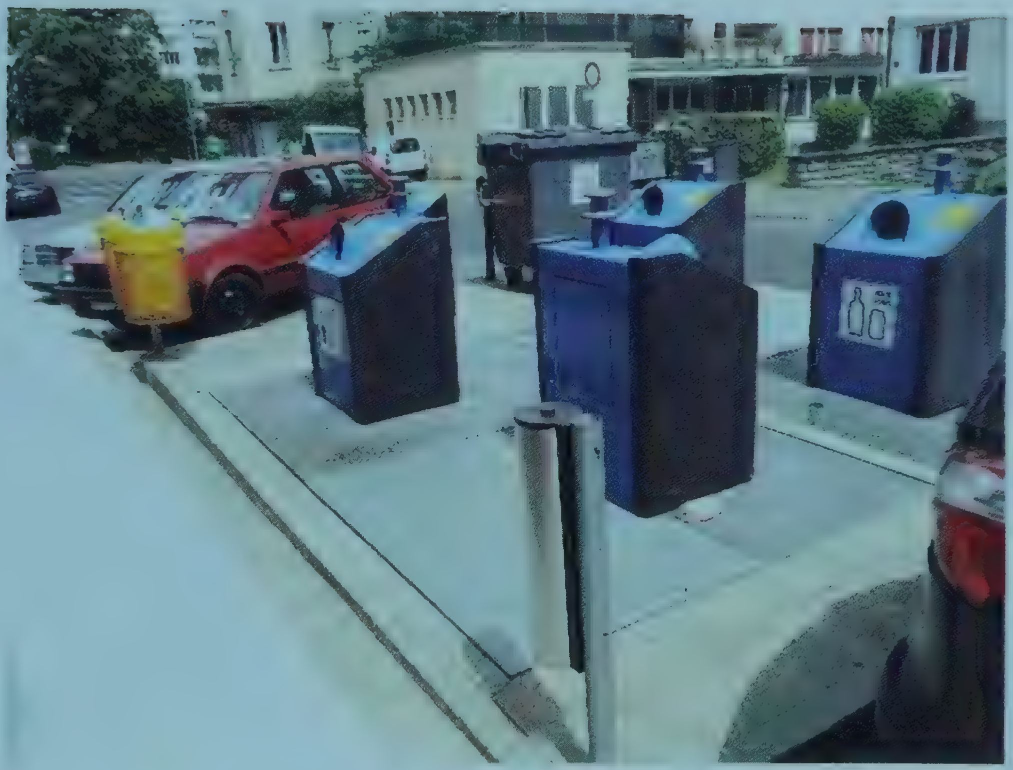


Fig. 5.13 Dustbins on Streets

Resting Places/Seats

Elderly and pedestrians with disabilities may need to take rest at reasonable intervals. Provision of resting places - simple sitting areas with chairs, benches or steps where one can have a break - is an important element of pedestrian spaces. Resting spaces and shelter should also be there where frequency is more.

- As with all street furniture, seating should be placed next to the footpath without obstructing it, and painted in contrasting colours. Seats can be as simple as wooden benches or perch-type rails to lean against.
- Seats should be 450mm and backrest 700mm high.
- It is helpful to people with sight problems if these and other amenity areas adjacent to walkways and pedestrian routes are picked out in contrasting colours.

Colour and Contrast

Street furniture should contrast in colour and in tone with the background against which it is seen and should be highlighted by means of a 75–100mm high feature, such as a crest or band, which contrasts in colour and tone with the furniture itself.

Furniture should be continuous to ground level. Avoid pedestal-mounted objects such as litter bins, telephones or letter boxes. Items attached to posts should face in the direction of travel so that they do not interfere with the line of movement. Where eye-level signs, such as maps, are supported on two vertical poles, a tapping rail located between the posts at around 250mm above ground level prevents an unsuspecting pedestrian colliding with the sign. The rail and posts should be colour contrasted with their background.

- In outdoor settings, seating should be provided along with the planned hawker spaces (**Fig. 5.14**);
- The spaces for hawkers should have provisions for their seating, loading and unloading of goods and nearby parking spaces for their assistive devices such as wheelchair, tri-cycles, etc; and

- General and accessible toilet facilities should be provided near resting areas and hawker spaces, especially near the markets, bus stops and terminals.

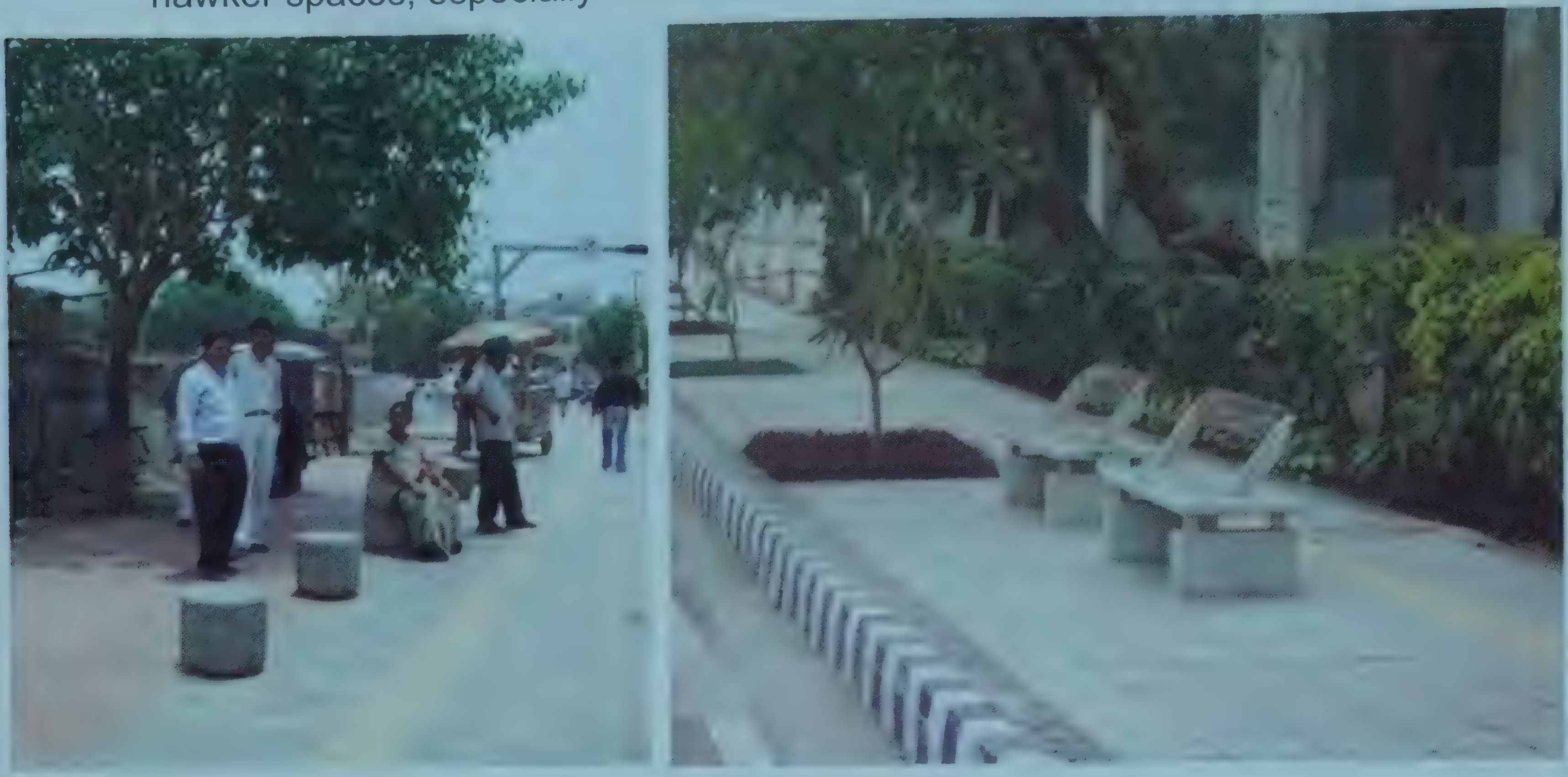


Fig. 5.14 Colour and Contrast

Dedicated Hawker Spaces

Most cities in India experience street vendors operating on urban streets. They are important service providers for road users including pedestrians. Usually, they are found encroaching the footpath or the left most lane of the carriageway, which affects the users.

- Allocation and Design of Hawker Space

The determinants for the design are as follows:

- **Location:** of the designated space should be such that the spill over of activities or clientele does not encroach the pedestrian path. However, additional spaces could be near auto rickshaw/short-term bays for cars that are clearly distinct from the other lanes/tracks/infrastructure. The ideal location is integrating the space after allocating space for the carriageway, lanes/tracks and pedestrian paths. The hawkers can then be integrated along the pedestrian path in case of arterials and along the carriageway between parking bays in a distributor street.

  Material: use of material can be same as that of the pedestrian path or a mix of materials can be used to evolve a pattern in the paving. It should be attractive enough for vendors to use it. The material should ensure no hindrance in drainage.

  Edge treatment: the edges could be designed using street furniture like benches and bollards.

  Access: space should be easily accessible by all types of hawkers. Some of the hawkers use bicycles and wheeled-carts. To ensure they are able to access such spaces, a mountable kerb could be designed. Another provision would be the use of ramps provided for level access for persons with disabilities using the feeder infrastructure.

Median/Pedestrian Refuge

- Pedestrian refuge is required for safe and barrier free road crossing, as many persons with reduced mobility cannot cross the road in one stretch as they feel exhausted.
- Uniformity in crossing distance should be maintained.

Pedestrian Traffic Signals

- Signal timings should be controlled as per the pedestrian volume and time interval allowed for crossing should be programmed according to the slowest crossing persons.
- Pedestrian traffic lights should be provided with clearly audible signals for the benefit of pedestrians with visual impairments (**Fig. 5.15**).
- Acoustic devices should be installed on a pole at the point of origin of crossing and not at the point of destination. In noisy areas, any spoken information should be repeated at least once. Audible traffic signals should operate at least 15dB over the prevailing sound level, with a maximum of 140dB.
- The installation of two adjacent acoustic devices such as beepers is not recommended in order to avoid disorientation; and
- Acoustical signals encourage safer crossing behavior among children as well.
- At mid-block pedestrian crossings, pelican type signals (push button) should be used.

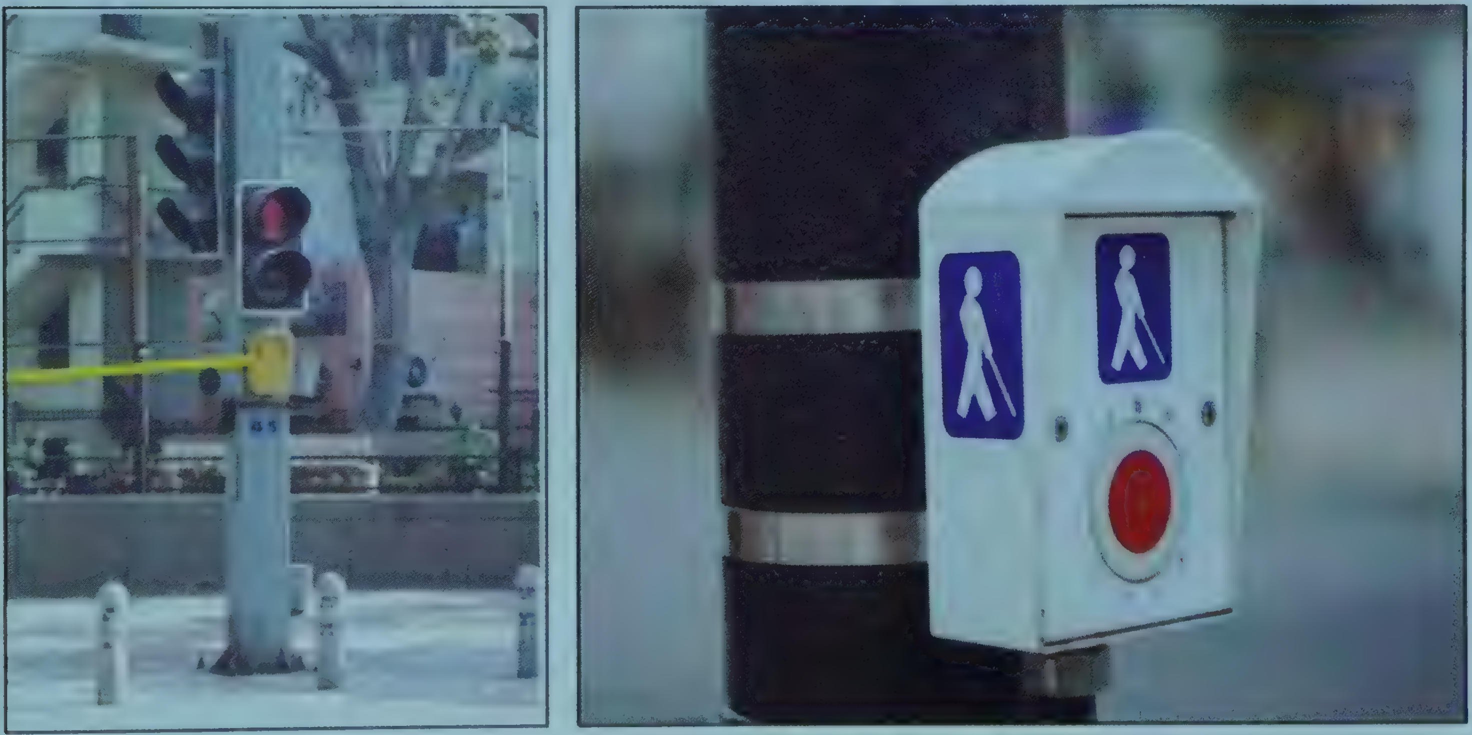


Fig. 5.15 Traffic Signal (Left) and Audio Signal (Right)

Parking

Cities must prioritize parking of non-motorised vehicles and IPT modes as these provide last mile connectivity to transit. Parallel parking configuration, where vehicles are parked parallel to the kerb, must be preferred over angular and perpendicular parking configurations for all three-wheeled and four-wheeled vehicles including motor cars, Light Commercial Vehicles (LCV), buses and trucks. Perpendicular parking configuration should be preferred for motorised two-wheelers as well as bicycles. Accessible parking places should be located close to an accessible entrance.

5.3 Underpasses

A subway/underpass is usually provided in those places where there is a high volume of traffic and it is not considered efficient to use a signal to intermittently stop the traffic flow. In such a situation, a subway allows the pedestrians to cross the road as well as access to the bus shelters without causing any delay to the traffic. The only negative aspect of a subway is that the pedestrians are required to walk more to cross a certain distance, which can be inconvenient.

Half Subway/Underpass

In such subways, both the car lane users and the pedestrians (including cyclists, wherever segregated facility is provided) need to have a change in level. The car lanes are raised (+1.5m) using a ramp of 1:30 and the pedestrian paths (cycle tracks, wherever provided) are lowered using ramps of slope 1:20 with landing at appropriate intervals to equally achieve a clear minimum height of 2.75m. (-1.5m). The advantage of such subways is that the walking length of a pedestrian is not increased to the extent that it discourages him from using it.

Full Subway/Underpass

In this case, the pedestrian paths are lowered to a depth where a clear height of 2.75m minimum can be achieved using 1:20 slope ramps with appropriate landings.

5.4 Foot over Bridges

Foot-over Bridges increase the walking length of a commuter for access. Such facilities need to be accessible to all. To make it inclusive pedestrian facility, ramps (gradient 1:20 with landing at adequate intervals), lifts and steps (landings at appropriate levels) can be provided.

To assist visually impaired people, tactile paving/tiles and a colour contrast should be provided at the top and bottom of the flight of steps and these areas should be well lit. Ramp/lift is mandatory and steps/escalators can be provided. Lift where provided should be on both the entrances/exits and should have minimum internal dimensions of 1500mm x 1500mm.

This grade separated alternative is of low priority.

5.5 Other Requirements

5.5.1 *Bus Stops*

All bus stops must be universally accessible. Bus Stops should preferably be located within the Multi-Functional Zone – so that they do not interfere with the clear walking zone for passing pedestrians at the back (**Fig. 5.16**).

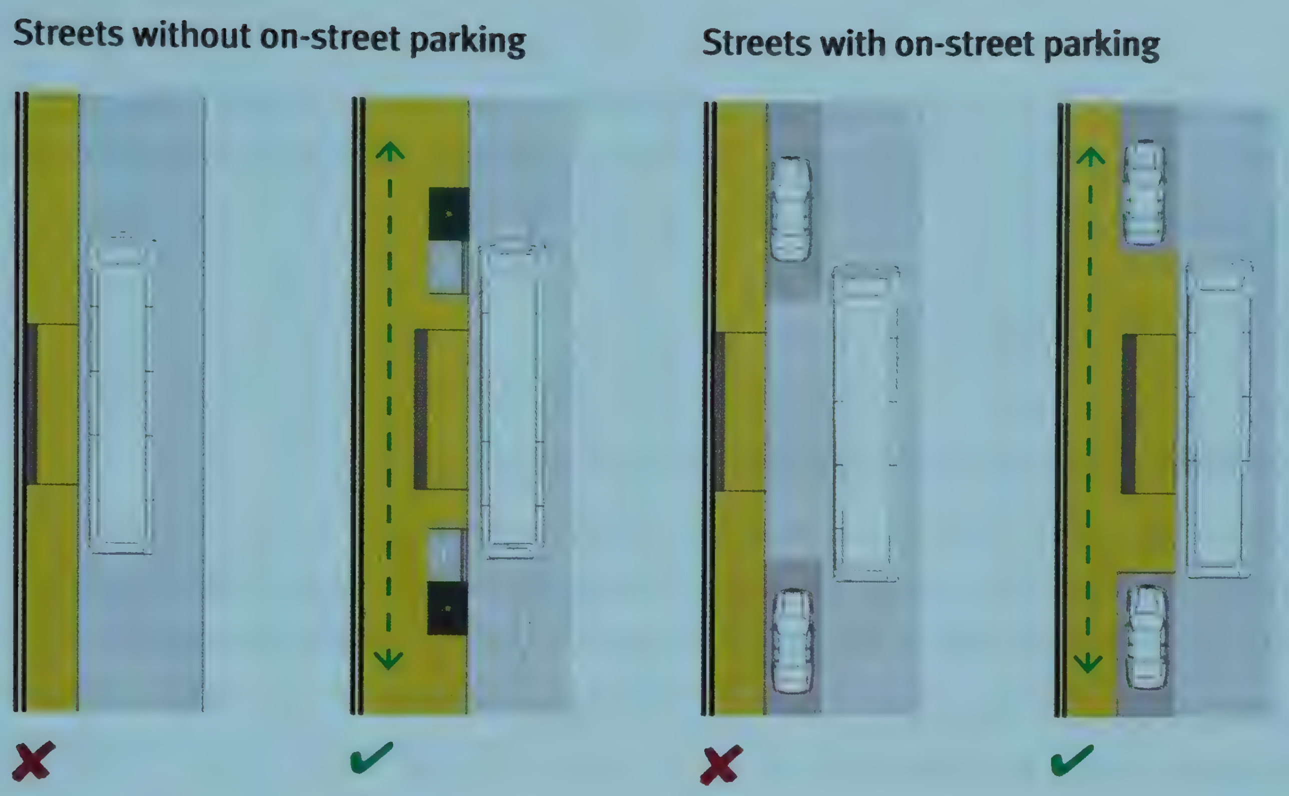

Streets without on-street parking
Streets with on-street parking
✗
✓
✗
✓

Fig. 5.16 Location of Bus Stops

- *Bus Stand/Stop*

  At least one accessible route should be provided from the alighting and boarding point of the bus stand to the walkway that leads to the accessible bus stand;

  Directional signs should be installed to direct persons with disabilities to an accessible entrance;

  Tactile guiding paver should be provided along the accessible walkway from the bus stand to the building entrance to aid persons with visual impairments; and

  The bus stand must have minimum illumination level of 35 lux.

Location

Bus stand should be located nearest to an accessible entrance; and where transfer is made from a vehicular surface to a pedestrian surface, the driveway, pathway or walkway should be blended to a common level or be ramped.

Passage width

A clear passageway with a minimum width of 1200mm should be provided.

Seats

Seats should be provided at the bus stand for persons with ambulatory disabilities and persons with reduced mobility. These seats should be positioned such as not to impede the movement of wheelchair users. Tactile paving should be provided to guide passengers with visual impairments to the seating areas.

Shelter

A shelter should be provided at the bus stand for protection against adverse weather conditions. It should be visually transparent tu enhance personal safety.

Ramps

Where a bus stand is not on the same level with the walkway or pathway, it should have two separate ramps for boarding and alighting; and where there are kerbs between the access aisle and the vehicle pick-up space, it should have a kerb ramp.

5.5.2 *Taxi/Auto Rickshaw Stand*

At least one accessible route should be provided from the alighting and boarding point of the taxi stand to the walkway that leads to the accessible building entrance;

- Directional signs should be installed to an accessible entrance;
- Guiding pavers should be provided along the accessible walkway from the taxi stand to the building entrance to guide persons with visual impairments;
- The sign indicating the presence of a taxi/auto stand shall be on a vertical pole and the sign should be visible after dark- minimum illumination level of 35 lux is required; and
- Where transfer has to be made from a vehicular surface to a pedestrian surface, the driveway, pathway or walkway should be blended to a common level or be ramped.

Passage Way

Continuity of the pedestrian pathway shall have minimum width of 1200mm behind the taxi stand.

Ramps

Where a taxi stand is not on the same level with the walkway or pathway, it should have two separate ramps for boarding and alighting; and

Where there are kerbs between the access aisle and the vehicle pick-up space, it should have a kerb ramp.

Seats

Seats may be provided at the taxi stand for persons with reduced mobility and disabilities; and these seats should be positioned such so not to impede the movement of wheelchair users and persons with visual impairments.

Shelter

A shelter should be provided at the taxi stand for protection against adverse weather conditions.

5.5.3 *Public Toilet*

Provide Public Toilets may be provided at strategic locations based on assessment of needs and demand.

5.6 Lighting

Personal security is especially important to vulnerable groups such as elderly people and women (including girls and women). Good lighting is particularly necessary for pedestrian crossings, public transport facilities and for car parks. Concentrated lighting is especially required where congregation of pedestrian is expected i.e. at bus stops, near crosswalks, near street furniture.

- Lighting shall be directed downward (**Fig. 5.17**) at all times (up-lighting should be prohibited).
- Lighting must be provided every 20–30m, focusing light on the pedestrian and bicycle lanes.
- Pedestrian lighting should illuminate the pedestrian walkway; appropriate lighting fixtures not exceeding a height of 4m from ground grade level should be provided.
- Recessed lighting on the ground along vehicular access ways and pedestrian walkways is highly encouraged.
- Wall-mounted lighting, besides reducing street furniture, ensures a more even distribution of light, reducing the risk of vehicle impact damage and reducing vandalism.
- All exterior lighting fixtures shall conform to the shielding requirements.
- A whiter light source is preferable in city and town centres for the aesthetic effect and for better colour definition, which benefits those with poor sight and highlight tactile pavers installed for persons with visual impairments. White lighting at 25-40 lux for footpaths is recommended, maintain colour contrast from road and ensure colour contrast of tactile tiles visible at night to persons with low vision.
- Location of lighting fixtures must consider the location of existing and proposed trees.
- Spacing of fixtures should be based on the intensity of light, height of the fixture and the clearances from tree canopies such that no light is blocked by the summer foliage.
- Higher lighting levels (80 lux) using special light poles for pedestrian crossing is recommended, while lower level light poles are preferred to avoid shadow where there are high trees.
- The lighting pole should not interfere with the clearance of the main pedestrian walkway of the footpath. Light pole may preferably be located within the tree-planting zone.

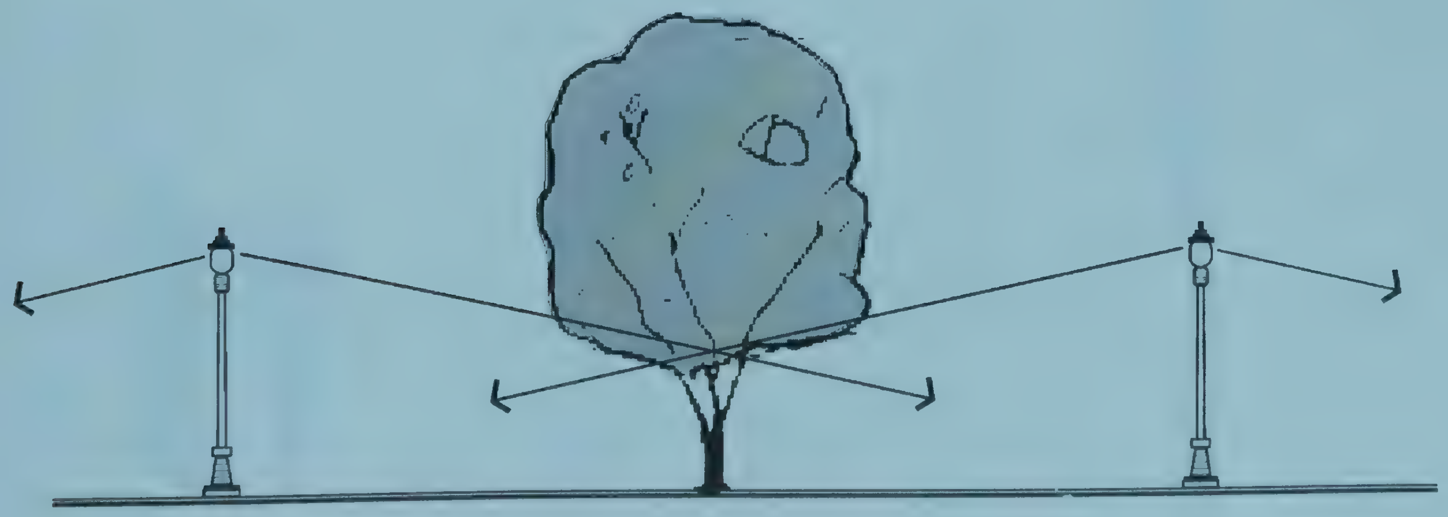


Fig. 5.17 Lighting directed downward, Poles spaced away from Trees

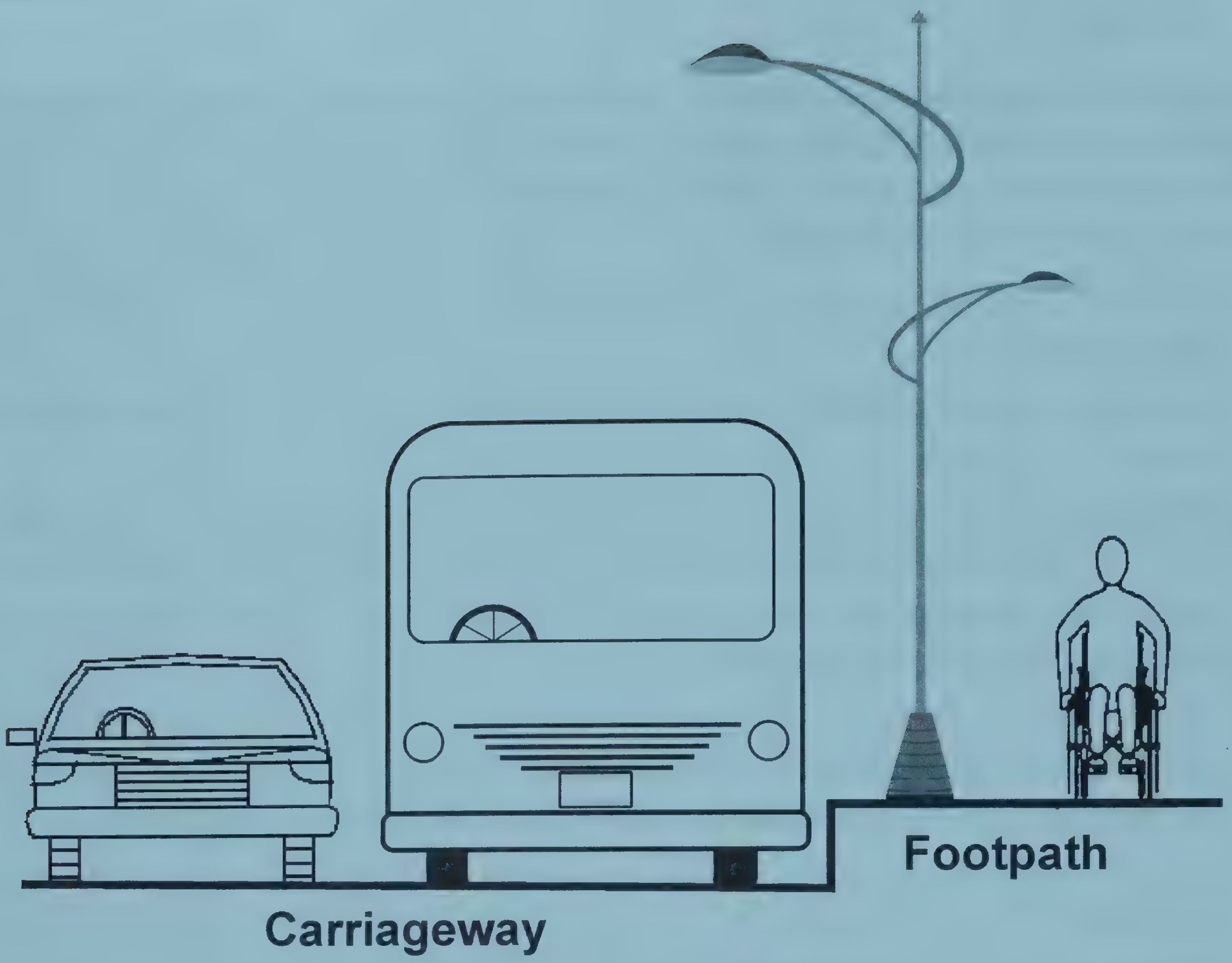

Footpath
Carriageway

Fig. 5.18 Lighting on the Footpath

CHAPTER 6

CYCLE TRACKS

6.1 NMV Infrastructure

Non-Motorized Vehicles (NMV) include cycles, tri-cycles, cycle rickshaws, push carts, etc. They also play an important role in provision of transport services.

Modal share in medium and large cities show that 13-21% of people cycle. It is an affordable means of transport for low income groups covering diverse accessibility needs.

In India, usually persons with disabilities from low economic groups use tri-cycle for employment/livelihood and/or essential activities such as education, health and socialization purposes. Tri-cycle users at times commute even long distances over 10 km.

A most effective option would be to segregate such users into separate tracks or paths along the road network, especially for arterial and sub-arterials; and increase signals timing for them (see **Fig. 6.1**). On other streets, there is a need for traffic calming so that cyclists are safe without segregated tracks.

Security from harassment on the streets also becomes an important consideration for NMV users especially for women and children. Planning and design elements that introduce eyes on the streets – by removing setbacks and compound walls, having active building fronts and mixed land use, and street vendors – need to become a part of the spatial planning to enhance security.

In addition, NMV infrastructure should meet the following criteria:

- Provision of infrastructure suitable to road typology, which is safe, comfortable and attractive.
- Parking spaces for NMV public modes.
- Signage placed at strategic locations for identification of NMV lanes.

(Dimensions in mm)

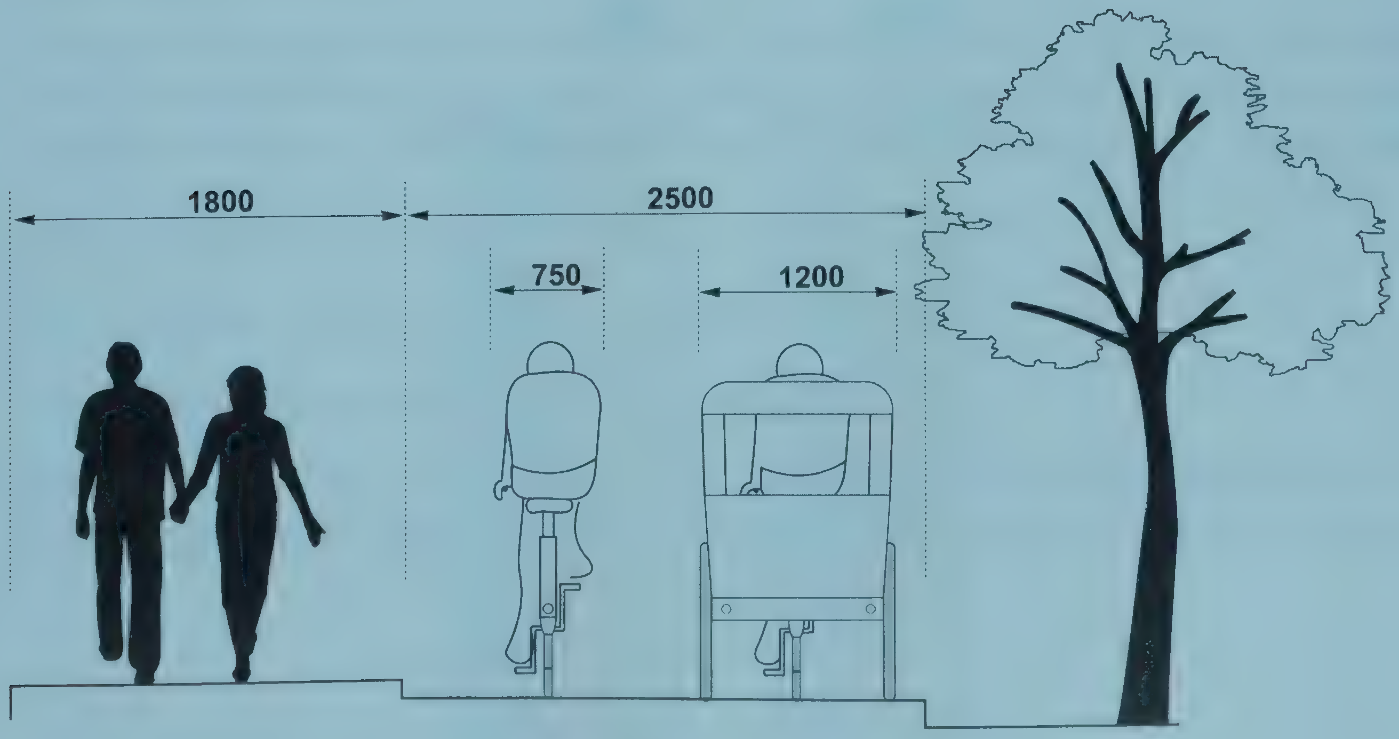


Fig. 6.1 Segregated NMV Track

6.2 Design Standards

6.2.1 *NMV Lane Design Considerations*

i. Provide adequate space—such as slow-speed shared spaces, footpaths, cycle tracks, and greenways – for NMV users.

ii. Accommodating NMV involves two simple techniques:

  - Pedestrian and cycle infrastructure be physically separated from motor vehicle traffic (by raised kerbs, vehicle parking lanes, bollards, landscaping, etc.) on wider streets.
  - Systematic traffic calming to ensure that shared streets are safe places for the mixing of pedestrians and other modes "shared lanes".

iii. Non-motorized vehicle infrastructure should be unobstructed, continuous, shaded, be well drained and well lit.

iv. Cycle stations (parking, sharing and hiring) should be arranged in a close space network so that a station is always within walking distance from any point in the coverage area.

v. Employ traffic calming elements (including speed humps, raised speed tables, bollards, roundabouts, and textured pavements) to ensure pedestrian and vehicle safety by reducing the speed of motor vehicles. Traffic calming elements are particularly important in places where large number of children are present, such as schools, parks, and residential areas.

vi. Avoid high, uneven and unmarked speed breakers as these are hazardous.

vii. Provide street lighting of 35-40 lux level to enhance visibility and safety on NMV facilities.

viii. A 0.5 m buffer is needed between a cycle track and motor vehicle or parking lanes. The buffer can accommodate ramps and storm water catch pits. The buffer should be paved if it is adjacent to a parking lane (**Fig. 6.2**).

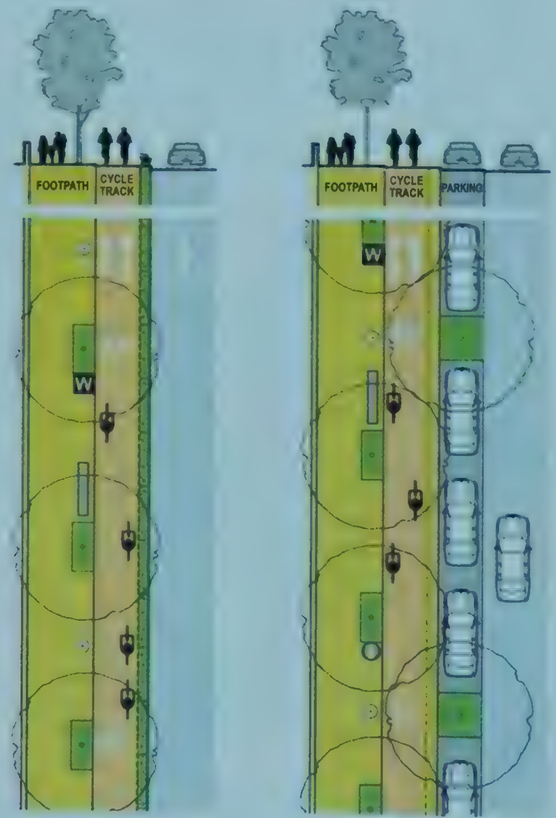


Fig. 6.2 Segregated NMV Lane

6.2.2 *Width of Cycle Track*

Width of cycle track is based on expected cycle traffic intensity during rush hours. **Table 6.1** gives the recommended width.

Table 6.1 Width of Cycle Track (Source: CROW Manual)

One-Way Track		**Two-Way Track**	
Rush hour intensity in one direction (b/h)	**Width (b)**	**Rush hour intensity in both directions (b/h)**	**Width (b)**
0-150	2.00 m (min.)	0-50	3.50 m (min.)
150-750	3.00 m	50-150	2.50 to 3.00 m
>750	4.00 m	>150	3.50 to 4.00 m

6.2.3 *Cross-Section*

The user with the basic dimensions of NMV should be understood by the road users. Therefore, develop cross sections, layout plans and design details for bicycle friendly infrastructure.

6.3 Other Design Elements

6.3.1 *Vehicle Types*

- *Cycles*

  Bicycles are used for trips in urban areas. They are also used to carry gas cylinders, milk cans, and for services such as post-delivery, telephone repair, garbage collection, etc. The bicycle is also used as a retail platform to display and sell products, like toys, cooked food, vegetables, fruit, etc.

- *Cycle Rickshaws*

  The cycle rickshaw is predominantly used as the main vehicle for commuting (mainly in small and medium sized cities and short trips to metro stations in large cities) since the trips are short, as also as feeder service to BRT and metro in long cities.

- *Goods Rickshaws*

  Tricycle carts are used for freight transport.

- *Tricycles for People with Disabilities (***Fig. 6.3***)*

  These are used by many persons with mobility impairments/disabilities for commuting as well as mobile telephone kiosks/eateries and serve as livelihood options.

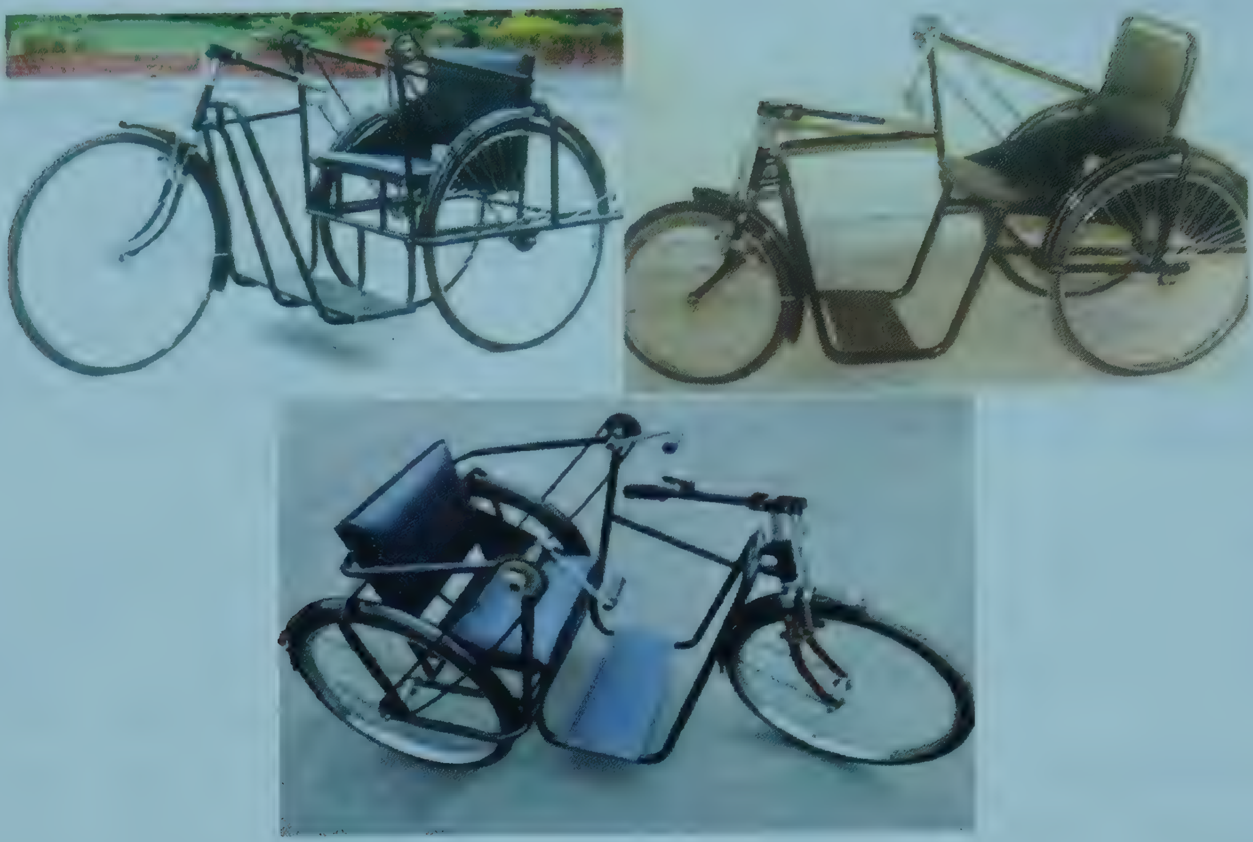


Fig. 6.3 Tricycle for People with Disability
(Source: ALIMCO: Tricycle)

6.3.2 *Speed Range*

The average speed range of NMT is 5km/hr to 10 km/hr depending on the type of cycle users ranging from hand driven cart used by hawkers to bicycles and rickshaws. It is important for cyclists to gain a cruising speed for constant usage. Interruptions due to parking, side roads and access to properties affect the desirable speed. Hence, variations in alignment, levels and form of the bicycle infrastructure may be avoided.

6.3.3 *Clearances and Widths*

Physical dimensions of various cycle types are given in **Table 6.2**. The width requirement of track for an NMV in movement is higher than its physical dimensions. This is on account of two main factors: zig zagging movement (side to side movement to maintain balance during riding) and fear of obstacles (or maintenance of manoeuvring gap). Bicyclists carrying goods and pillion riders may experience higher zig zagging on account of the extra weight carried, while cycle rickshaws experience minimal or no zigzagging. The distance that NMV maintain for fear of obstacles depends on the height of the obstacle. **Fig. 6.4** and **Table 6.3** indicate the variations in width and clearances from different obstacles.

Table 6.2 Dimensions of Cycles

Type of Cycle	**Length (mm)**	**Height (mm)**	**Width with rider (mm)**	**Handle bar width (mm)**	**Wheel size (dia. in mm)**
Adult Touring Bike	1950	1200	750	600	710
Adult Touring Bike with goods (milk cans or gas cylinders)	1950	1200	950	600	710

Type of Cycle	Length (mm)	Height (mm)	Width with rider (mm)	Handle bar width (mm)	Wheel size (dia. in mm)
Passenger Rickshaw	2200	1200	1000	600	710
Goods Rickshaw	2400	1200	1220	600	710
Modified Goods Rickshaw	2600	1200	1400	600	710

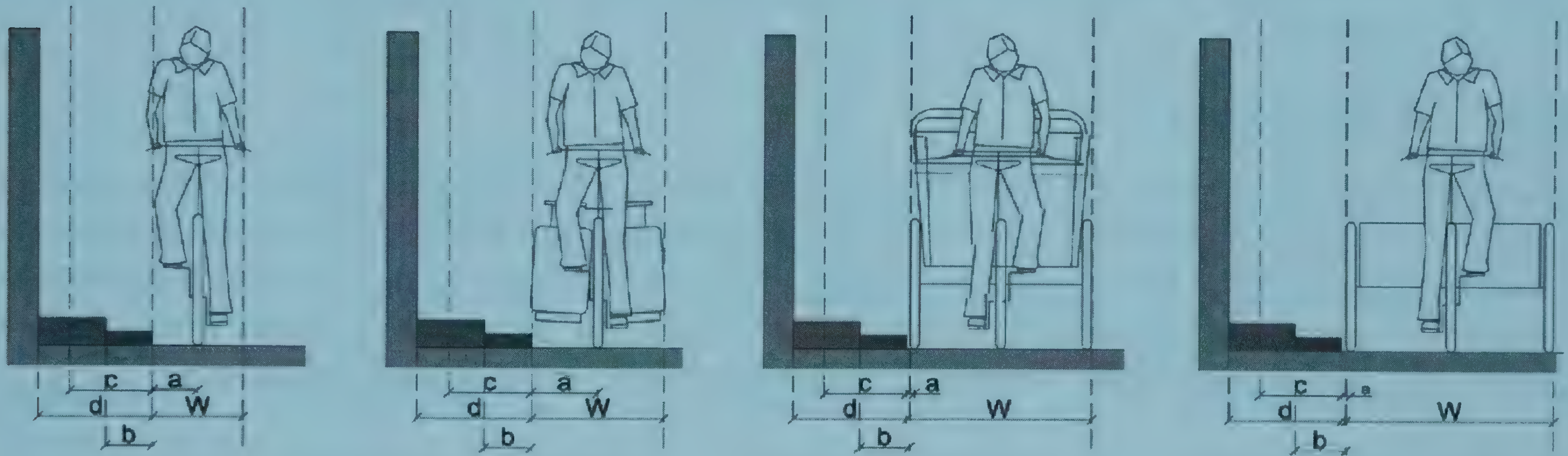


Fig. 6.4 Space Dimension for NMV

Table 6.3 Clearances and Widths (in mm)

	Total Width (as per cycle type) (mm)	Total clearance from obstacles (height of obstacle 0-50 mm	Total clearance from obstacles (height of obstacle 50-150 mm)	Total clearance from obstacles regarding fixed objects like poles and bollards (mm)	Total clearance from fear of obstacles regarding closed walls (from body edge) (mm)
	W	**a**	**b**	**c**	**d**
Adult Touring Bike	750	0	125	325	625
Adult Touring Bike with goods (milk cans or gas cylinders)	950	0	325	325	625
Passenger Rickshaw	1000	250	325	325	625
Goods Rickshaw	1220	250	325	325	625
Modified goods rickshaw	1400	250	325	325	625

6.3.4 *Coherence*

Coherence relates to the connectivity of the bicycle network. This implies that the segments in the network should look similar to improve usability of the bicycle infrastructure. Elimination of any missing links as well as standardization of intersections i.e. the shape, size and form of each category of junction solution should be similar to help the cyclist in being aware of vehicular behavior in the traffic mix. Also, use of various measures like road markings, signs and traffic calming measures across intersections improves coherence.

6.3.5 *Directness*

Directness of bicycle infrastructure has to do with the amount of time and effort required by a cyclist to undertake a journey. Therefore, major detours from their natural path may be avoided as far as possible.

6.3.6 *Attractiveness*

To enhance attractiveness, the path of the cyclist should be clean and devoid of any dumped material that blocks movement. Such a blockage would prevent the cyclist from using the cycle infrastructure and force him to use the carriageway exposing him to risk of unsafe conditions. Location of spaces for hawkers and vendors, well integrated bus shelters, green areas, resting spaces, etc. and shaded NMV infrastructure are factors that enhance attractiveness.

6.3.7 *Safety and Security*

Prevention of collisions and reducing the conflicts and their impact will result in a safer travel. Provision of adequate and uniform lighting ensures enhanced usability as well as safer streets. Integration of spaces for hawkers and vendors, support facilities provides security and the necessary eyes on street. Safer Intersections can be provided by minimizing conflicts (and sub-conflicts).

6.3.8 *Comfort*

The surface of cycle track should be even and free of cracks and potholes. Riding surface for cyclists at the intersection should be smooth to improve comfort. Water logging in the path of cyclist areas is uncomfortable and therefore it is important that proper drainage should be provided with regular maintenance.

6.4 Treatment at Intersections

The intersection design forms an integrated part of the overall route for an NMV user. Based on the types of roads intersecting, junctions can be classified as signalized intersection, un-signalized intersection or roundabout.

Traffic lights are a less (sustainably) safe solution than geometrically designed roundabouts or grade separated intersections and must therefore be regarded as second best in terms of safety. Intersections created within and between each road type present varying challenges to directness, safety, comfort and the attractiveness of NMV infrastructure. **Table 6.4** gives an indication of various possible solutions.

Table 6.4 Accident Severity and Intersection Solutions

	Arterial Roads	Collector Streets	Local Streets
Arterial Roads	• Accident Severity: 1 • Recommended crossing - – Roundabouts (3,4 arm) – Signalized Crossings (3,4 arm) – Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	• Accident Severity: 2 • Recommended crossing - – Roundabouts (3,4 arm) – Signalized Crossings (3,4 arm) – Grade Separated Crossing for cyclists along Distributor road (4 arm only)	• Accident Severity:4 • Recommended crossing - – Traffic calmed crossing (3 arm only – access street opening on to an arterial road) – Grade Separated Crossing for cyclists along access road
Collector Streets	• Roundabouts • Signalized Crossings (3,4 arm) • Grade Separated Crossing for cyclists along Distributor road (4 arm only)	• Roundabouts • Signalized crossing	• Roundabouts • Un-signalized/Traffic Calmed Crossing (3, 4 arm)
Local Streets	• Traffic calmed crossing (3 arm only – access street opening on to an arterial road)	• Roundabouts • Un-signalized/Traffic Calmed Crossing (3, 4 arm)	• Un-signalized/Traffic Calmed Crossing (3, 4 arm) • Mini Roundabout

6.5 Treatment at Grade Separators

Grade separated infrastructure needs to address requirements of both current and potential cyclists. In some situations, this approach may require provision of both, at grade and grade separated crossing facilities to address different requirement for various NMV users. Grade separation of intersecting motorized vehicle carriageway (flyovers, etc) is not desirable within the built-up areas or urban limits due to their adverse impact on accidents, pollution, etc. However, grade separation of cycle and pedestrian traffic across high-speed and high volume motorized vehicle carriageway may be advisable to enhance safety of cyclists and pedestrians.

CHAPTER 7

PAVEMENTS: DESIGN, CONSTRUCTION AND MAINTENANCE

A. DESIGN

7.1 General

Pavement design guidelines for urban roads are divided into two parts (i) New pavement design and (ii) Requirement of overlay on existing pavement based on functional and structural evaluation of urban roads. The pavement for urban roads should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil
- Structurally strong to withstand all types of stresses imposed upon it
- Adequate coefficient of friction to prevent skidding of vehicles
- Smooth surface to provide comfort to road users
- Cause low noise pollution from moving vehicles
- Dust proof surface so that traffic safety is not impaired by reduced visibility
- Impervious surface, so that sub-grade soil is well protected
- Long design life with low maintenance cost
- Achieve environmentally optimised and climate resilient design

7.2 Concept

Road is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the stresses transmitted due to wheel load do not exceed the allowable stresses on the soil sub-grade. Three types of pavements are generally recognized as serving this purpose, namely flexible pavements (**Fig. 7.1**), rigid pavements (**Fig. 7.2**) and composite pavements. Composite pavements are a combination of thin layer of flexible pavement over rigid pavement or vice-versa. However, composite pavements are not recommended in new construction because of high cost and complex analysis required.

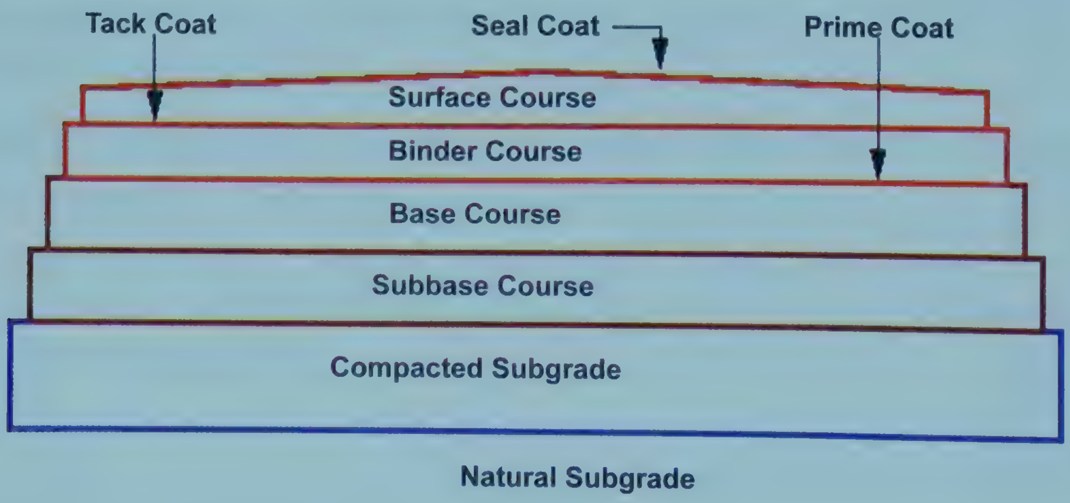


Fig. 7.1 Typical View of Conventional Flexible Pavement with Different Layers

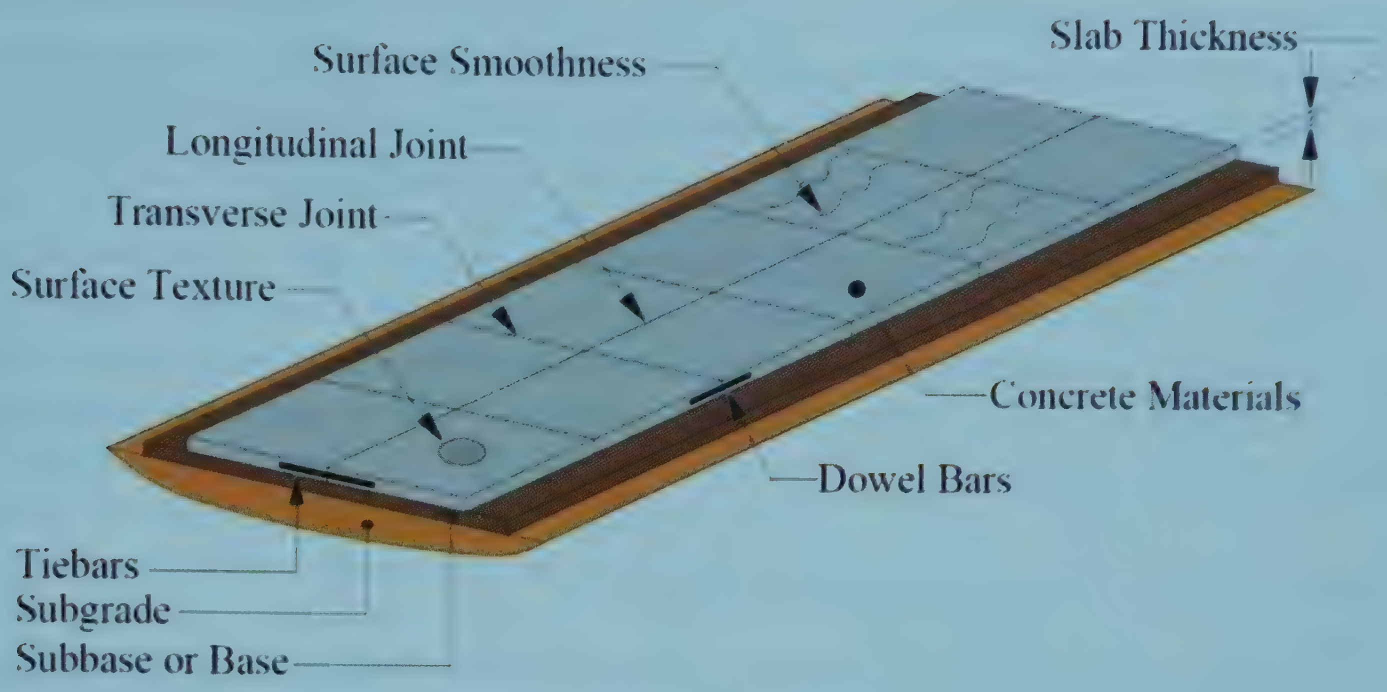


Fig. 7.2 Typical View of Jointed Plain Reinforced Concrete Pavements

7.3 New Pavement Design

There are three categories of pavements which are Flexible, Rigid and Composite Pavements

7.3.1 *Flexible Pavements*

Generally, in sub-urban areas/urban areas where expansion of cities is taking place, the possibility of green field projects related to new pavement construction, as well as, reconstruction of damaged pavements for roads with a design of two Million Standard Axle (msa) load repetitions or more, does exist. For such cases, the current guidelines on design of flexible pavement, IRC:37 should be followed.

The new form of construction and materials such as stone matrix asphalt, modified bitumen, foamed bitumen, bitumen emulsion, warm asphalt, Cement Treated Bases (CTB) and Cement Treated Sub-Bases (CTSB) have also been included in pavement design with their applications. Commercially available chemical soil stabilizers which have been successfully used in trial sections are also covered. The need for environmentally optimised design is shifting focus from large scale use of conventional aggregates to use of local, recycled and engineered marginal aggregates in construction. The following aspects should be given consideration while designing to achieve better performing pavements:

i) Adopt a design period of twenty years.
ii) Computation of effective CBR of subgrade for pavement design.
iii) Use of rut resistant surface layer.
iv) Use of fatigue resistant bottom bituminous layer.
v) Selection of surface layer to prevent top down cracking.
vi) Use of bitumen emulsion/foamed bitumen treated Reclaimed Asphalt Pavements in base course.
vii) Consideration of stabilized sub-base and base with locally available soil and aggregates.

viii) Design of drainage layer.

ix) Computation of equivalent single axle load considering (a) single axle with single wheels (b) single axle with dual wheels (c) tandem axle and (d) tridem axles.

x) Design of perpetual pavements with deep strength bituminous layer.

The IRC Guidelines (Section 6, IRC:37) also brought out the concept of effective modulus/CBR for design of flexible pavements. It says where there is significant difference between the CBRs of the select soil sub-grade and embankment soils, the design should be based on effective modulus/CBR. Sections 6.3 and 6.4 of IRC:37 elaborate the method of obtaining effective modulus/CBR of the soil sub-grade.

7.3.2 *Philosophy of Flexible Pavement Design*

The philosophy of pavement design involves designing pavements for satisfactory functional and structural performance of the pavement during its intended service life period. Roughness caused by variation in surface profile, cracking of layers bound by bituminous or cementitious materials, rutting (permanent or plastic deformation) of unbound/unmodified or partially modified subgrade, granular layers and bituminous layers are the primary indicators of the functional and structural performance of pavements. Performance of the pavement is explained by performance models which are either (a) purely empirical (only based on past experience) or (b) mechanistic-empirical, in which the distresses/performance are explained in terms of mechanistic parameters such as stresses, strains and deflections calculated using a specific theory and as per specified procedure. Most of the current pavement design methods follow the mechanistic-empirical approach for the design of bituminous pavements. In these methods, for each of the selected structural distresses, a critical mechanistic parameter is identified and controlled to an acceptable (limiting) value in the design process. The limiting values of these critical mechanistic parameters are obtained from the performance models.

The mechanistic-empirical design approach, which was used in the earlier revisions of IRC:37, is retained in the current revision (IRC:37) as well for the design of flexible pavements. The theory selected for the analysis of pavements is ‘linear elastic layered theory’ in which the pavement is modeled as a multi-layer system. The bottom most layer (foundation or subgrade) is considered to be semi-infinite, and all the upper layers are assumed to be infinite in the horizontal extent and finite in thickness. Elastic modulus, Poisson’s ratio and thickness of each layer are the pavement inputs required for calculation of stresses, strains and deflections produced by a load applied at the surface of the pavement. IITPAVE software, which is an updated version of FPAVE has been used for the analysis of pavements. The detail of the software has been given in Annex-I of IRC:37.

The vertical compressive strain (ϵ_v) on top of the subgrade is considered to be the critical mechanistic parameter for controlling subgrade rutting. Horizontal tensile strain (ϵ_t) at the bottom of the bituminous layer is taken as the causative mechanistic parameter which has to be limited to control bottom-up cracking in bituminous layers. Similarly, to ensure that the Cement Treated Bases (CTB) do not fail by fatigue cracking, tensile strain and tensile stress at the bottom of the CTB are considered to be the critical parameters to control.

Rutting within bituminous layers caused by accumulated plastic (permanent) deformation in these layers, moisture damage of mixes and brittle cracking resulting from excessive age hardening of bitumen in the upper layers are the other major concerns to be taken into consideration. These distresses are considered by integrating the mix design into the structural design by incorporating the mix volumetric parameters into the performance models and by making suitable recommendations about the choice of binder and mix to be used in different layers.

The pavement sections are to be selected in such a way that they satisfy the limiting stresses and strains prescribed by the performance models adopted in Section 3.6 of IRC:37 for subgrade rutting criteria (80% and 90% reliability equations), fatigue cracking criteria (80% and 90% reliability equations) and fatigue performance models for Cement Treated Bases (CTB). Additional measures have also been suggested in the guidelines by way of integrating the mix design parameters that have a significant bearing on the performance of pavements into the design process (section 3.6.2 of IRC:37). Suitable recommendations have also been made for (i) fatigue cracking and moisture damage resistant mixes for the bottom (base) bituminous layer (ii) rut and moisture damage resistant bituminous mixes for the intermediate (binder) bituminous layer (if provided) and (iii) rut, moisture damage, fatigue cracking and age resistant surface course and (iv) drainage layer for removal of excess moisture from the interior of the pavement.

7.3.2.1 Analysis of flexible pavements

The standard conditions recommended for the pavement analysis is present in (Section 3.8 of IRC:37). The vertical compressive strain on top of subgrade and the horizontal tensile strain at the bottom of the bituminous layer are considered to be the critical mechanistic parameters which need to be controlled for ensuring satisfactory performance of flexible pavements in terms of subgrade rutting and bottom-up cracking of bituminous layers. Similarly, the horizontal tensile stress and horizontal tensile strain at the bottom of the CTB layer are considered to be critical for the performance of the CTB bases.

Different pavement structural catalogues (plates) are presented in the IRC:37 guidelines for design traffic levels up to 50 msa. For all roads with more than 2 msa design traffic, the design shall be carried out using site specific inputs to satisfy the mechanistic-empirical performance models given in the guidelines which may require analysis of different trial pavement sections using IITPAVE software. The actual optimal requirement of layer thicknesses shall be evolved based on detailed analysis.

The catalogues (plates) given in the guidelines are for the following six categories of pavements: (a) bituminous surface course with granular base and sub-base (b) bituminous surface course with CTSB, CTB and granular crack relief layer (c) bituminous surface course with CTSB, CTB and SAMI (d) bituminous surface course with CTSB and emulsion/foam bitumen stabilised RAP/virgin aggregate (e) bituminous surface course with GSB, CTB and granular crack relief layer and (f) bituminous surface course with CTSB and granular base course. Pavement structural composition and catalogues (plates) have been given for six categories of pavements. For catalogues (plates) of pavement structural composition with further details, IRC:37 should be referred.

7.3.3 *Porous Asphalt Pavements*

Porous asphalt pavements are specially designed pavements that use Porous Asphalt Concrete (PAC) mixes to laterally or vertically drain storm water runoff. PAC mixes have traditionally been used as surface courses on new asphalt pavement structures or as part of HMA overlays placed on existing pavements. Sometimes referred to as Open-Graded Surface Courses (OGSC) or Porous/Permeable Friction Courses (PFC). These pavements are promising for rain water harvesting and are being used widely for parking areas, etc. especially in urban areas. These are water harvesting pavements and can be designed for ground water charging or for irrigation purpose. There can be many other usages of stored water obtained from pervious pavements.

Criteria: The ingredients of porous asphalt are course aggregates, modified bitumen, cellulose fiber and filler. Typical gradation of aggregate for porous asphalt is given in National Asphalt Pavement Association (NAPA), 2003.

Applications: OGSC/PFC pavements have continued to be used on many types of pavement facilities, from high volume freeways and major airport runways to low-volume roads which include urban roads also. They are generally not suitable for intersections or locations with heavy turning movements, nor for areas prone to heavy snowfall or subject to a lot of dirt or debris.

Benefits: The overall benefits of porous asphalt pavements may include both environmental and safety benefits including improved storm water management, improved skid resistance, reduction of spray to drivers and pedestrians, as well as a potential for noise reduction.

7.3.4 *Stone Matrix Asphalt*

Stone Matrix Asphalt (SMA), also called as stone mastic asphalt is a durable, rut-resistant wearing course using a gap-graded aggregate structure and modified bitumen with higher bitumen contents. SMA wearing course can primarily be used for high volume highways, urban arterial roads and approaches to intersections. In addition to improved durability, skid and rutting resistance, it is also effective in reducing traffic noise. IRC:SP:79 provides complete insight on the design process which needs to be followed for application.

7.3.5 *Rigid Pavements*

A cement concrete (rigid) pavement is a structure comprising of a layer of portland cement concrete which is usually supported by a sub-base layer on the soil sub-grade. It has sufficient flexural strength to transmit the wheel load stresses to a wider area below. Rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub-base course.

Concrete pavements may be either unreinforced (plain) or reinforced depending on the designers choice based on the local conditions and control of shrinkage cracking. IRC:58-2015 is to be followed for the design of plain jointed cement concrete pavements with and without tied concrete shoulders. These are applicable to roads having an average daily commercial vehicle more than 450 with laden weight exceeding 3 tonnes. The design procedure is at par with current trends considering cumulative fatigue damage due to the combined effect of load and pavement temperature. It also includes design of pavements with widened outer lane, tied concrete shoulders, pavements bonded to stabilized sub-base as well as design of longitudinal, expansion and contraction joints.

7.3.5.1 Types of Concrete Pavements

There are three main types of rigid pavement as given below:

Jointed Plain Concrete Pavements (JPCP): These are plain cement concrete pavements constructed with closely spaced contraction joints. Dowel bars or aggregate interlocks are normally used for load transfer across joints.

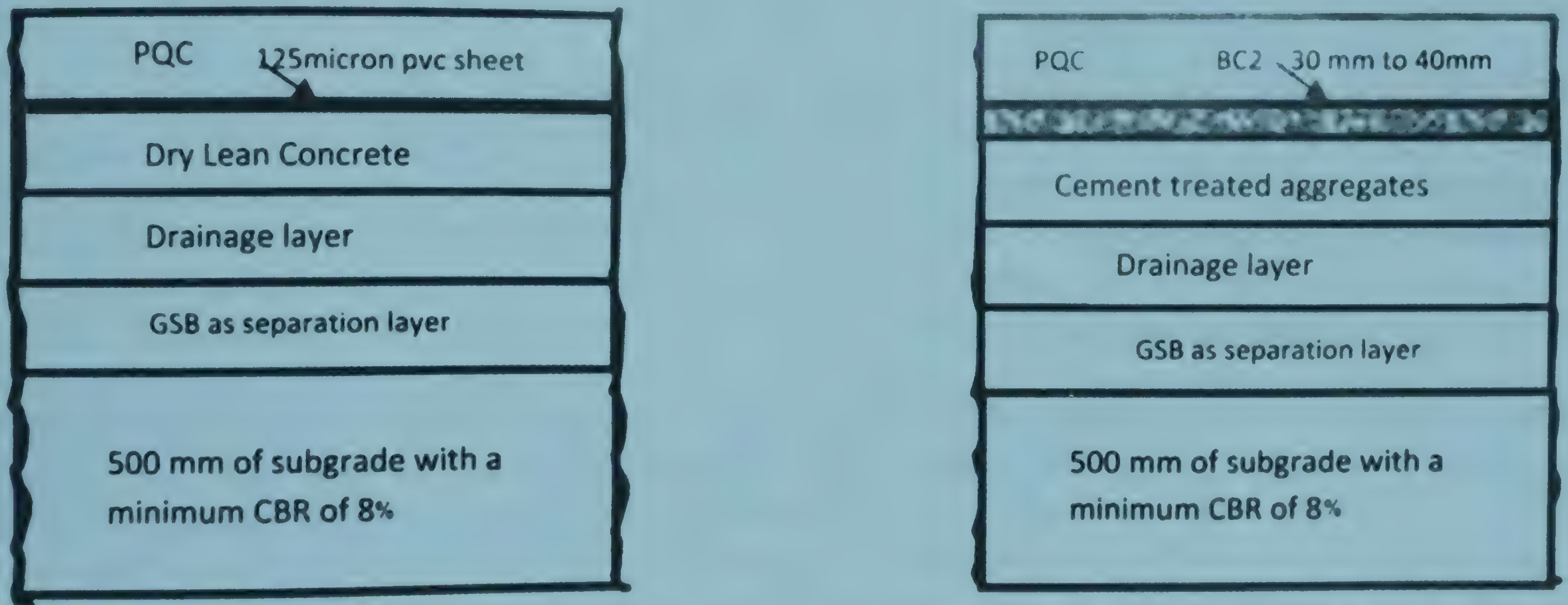
Jointed Reinforced Concrete Pavement (JRCP): Although reinforcements do not improve the structural capacity significantly, they can increase the joint spacing and dowel bars are required for load transfer. Reinforcements help to keep the slabs together even after cracks.

Continuously Reinforced Concrete Pavement (CRCP): There is complete elimination of joints which is achieved by steel reinforcement.

The type of concrete pavements in urban areas may depend upon the climate, availability of materials, soil types, experience and traffic. Typical cross-sections of two pavements are presented in **Fig. 7.3** as given in IRC:58. When Pavement Quality Concrete (PQC) is laid over a bituminous surface during the sunshine, it is important to whitewash the bituminous surface because black body absorbs more heat which may be injurious to concrete.

7.3.6 *Principles of Rigid Pavement Design*

The basic principle of rigid cement concrete pavement design is that tensile stresses in the cement concrete slabs are below its flexural strength.


PQC
125micron pvc sheet
Dry Lean Concrete
Drainage layer
GSB as separation layer
500 mm of subgrade with a minimum CBR of 8%
PQC
BC2
30 mm to 40mm
Cement treated aggregates
Drainage layer
GSB as separation layer
500 mm of subgrade with a minimum CBR of 8%

(a) Debonding Layer of Polythene Sheet Over DLC

(b) Debonding Layer of 30 to 40 mm BC2 Over Cement Treated Aggregate Subbase Layer

Fig. 7.3 Typical Cross Section of Concrete Pavement

It is further assumed that a rigid pavement, because of its rigidity and high modulus of elasticity, tends to distribute the load over a relatively wide area of soil, and thus the structural capacity is supplied by the slab itself. The rigidity of cement concrete slab may, however, lead to a false conclusion that the quality and properties of sub-base and soil sub-grade have no importance for rigid pavement behaviour, which may result in under design of the slab thickness. Therefore, in a rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium. It is analyzed by plate theory instead of layer theory, assuming an elastic plate resting on viscous foundation. Bending of the slab is due to wheel load and temperature variations and the resulting tensile and flexural stress.

7.3.7 *Factors Governing Design of Concrete Pavement*

The main factors governing design of concrete pavements are design period, design commercial traffic volume, composition of commercial traffic in terms of single, tandem, tridem and multi axles, axle load spectrum, tyre pressure, lateral placement characteristics, directional distribution, strength of foundation and climatic considerations. For detailed procedure to design a concrete pavement and construction of concrete pavements refer to IRC:58 and IRC:15, respectively.

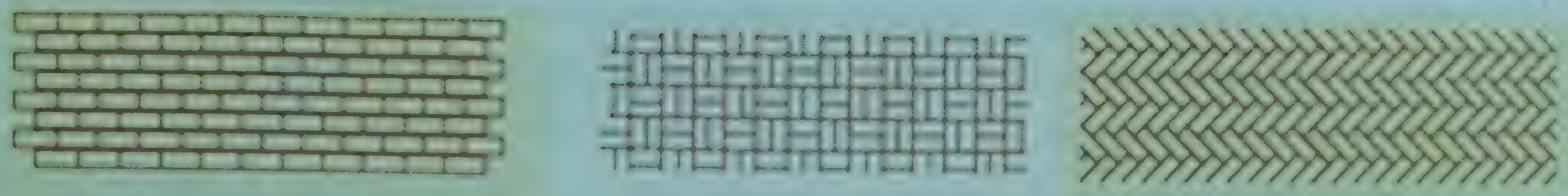
The Salient Features of IRC:58 are detailed below:

i) Design of pavements considering the flexural stress under the simultaneous action of load and temperature gradient for different categories of axles.
ii) Design considering sum of cumulative fatigue damages caused by single, tandem and tridem axle load applications due to tensile flexural stresses at the top and the bottom of the pavement slab.
iii) Consideration of in-built permanent curl in the analysis of flexural stresses.
iv) Design guidelines for pavements without concrete shoulders and with tied concrete shoulders.
v) Consideration of concrete slabs with unbonded as well as bonded cement bound subbase.
vi) Design of pavements with widened outer lanes.

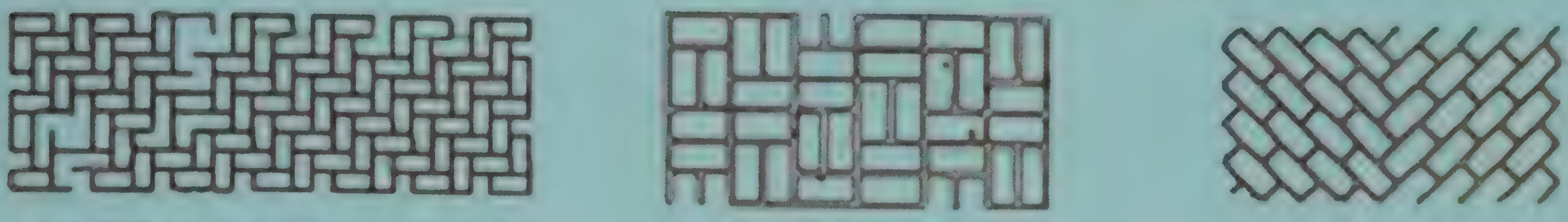
The IRC:15 deals with various aspects of jointed plain concrete pavement construction such as materials, equipment, proportioning, measurement, handling of materials, and mixing subgrade and sub-base preparation, formwork, joints, reinforcement of concrete, placing, finishing, curing, evaluation for acceptance criteria.

7.3.8 *Concrete Block Pavements (CBP)*

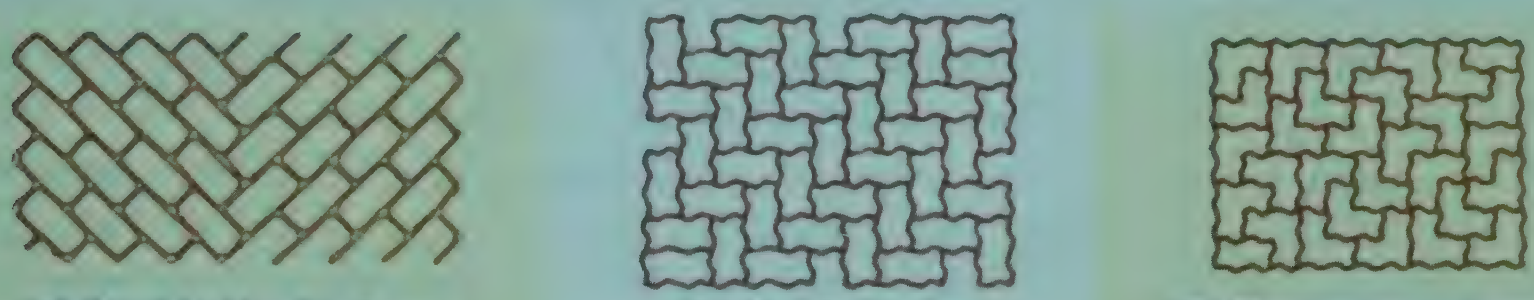
In view of the superior load distributing characteristics, concrete block pavements have been conservatively designed. Both rectangular and shaped, interlocking blocks may be used in pavements. Concrete block pavements are acceptable for low speed road and also for industrial road surfacing. They are not recommended for Expressways, National Highways, State Highways and Major District Road (MDR). However, if an MDR or State Highway passes through built-up area, their use is permitted. They are capable of supporting heavy and abrasive loads, require less maintenance, and offer easy subsurface access for utility repair or corrections for settlement. **Fig. 7.4** presents some laying pattern for CBP.



(a) Stretcher or Running Bond **(b) Parquet or Basket weave** **(c) 45° Herringbone Bond**



(d) 90° Herringbone Bond **(e) Parquet Derivative** **(f) Double-V**



(g) Double Herringbone **(h) Herringbone** **(i) Herringbone Bond**

Fig. 7.4 Various Laying Patterns of CBP

There are many international specifications of CBP including Indian specifications and can be referred for construction and application for urban roads. These specifications are detailed below:

a) IRC:SP:63 — Guidelines for the Use of Interlocking Concrete Block Pavement

b) Specification for precast concrete blocks for paving is IS:15658:2006

c) EN 1338:2003 (E), Concrete Paving Blocks — Requirements and Test Methods, European Committee for Standardization, Rue de Stassart, 36, B 1050, Brussels

d) CAN3-A23 1.2-M85 Pre-cast Concrete Pavers, Canadian Standards Association

e) AWNZS 4456.5:1997 — Masonry Units and Segmental Pavers- Methods of Test-Method 5: Determining breaking load of segmental paving units

CBP consists of a surface layer of small-element, solid un-reinforced pre-cast concrete paver blocks laid on a thin, compacted bedding material which is constructed over a properly profiled base course and is bounded by edge restraints/kerb stones. The block joints are filled using suitable fine material. A properly designed and constructed CBP gives excellent performance when applied at locations where conventional systems have lower service life due to a number of geological, traffic, environmental and operational constraints. Many such applications are used for light, medium, heavy and very heavy traffic conditions are currently in practice around the world and also suitable for urban roads.

Advantages:

1) Since the blocks are made in the factory, they are of good quality.

2) The block pavements are ideal for intersections where speeds have to be restricted and turning stresses are high.

3) These pavements, being of rough surface are skid resistant.
4) Digging and reinstatement of trenches for repair to utilities is easier.
5) Can perform better at bus stops, bus depots and parking areas.
6) Block pavements do not need in-situ curing and so can be opened to traffic soon after completion of construction.
7) Maintenance of block pavement is simple and easy. Also, the need for frequency of maintenance is low.
8) Block pavement does not exhibit high deterioratory effect due to thermal expansion and contraction, and is free from the cracking phenomenon.

Limitations:

1) Concrete block pavements cannot be used for high speed facilities.
2) The riding quality is reasonably good for low speed traffic, but is inferior to that observed on a machine laid bituminous or concrete pavement.
3) The noise generated is higher than bituminous and cement concrete pavements.
4) Regular and close attention to pavement drainage is needed because the water can seep through joints.

7.3.9 *Composite Pavements*

At present there are no Indian guidelines for composite pavements though there are lot of literature available on design principles of composite pavements which can be followed based on their best practices and local adaptability. Presently, construction agencies are facing the challenge of sustainable pavements (using recycled materials) and economical in rehabilitating pavements, while also providing a long service life. On the other side, challenge of having a limited source of quality aggregates has added to cost of importing materials. Pavements that combine new asphalt over concrete or vice versa, generally have a long service life with good surface characteristics, structural capacity and the ability to be renewed. However, the majority of roads containing these composite pavements have resulted from maintenance and rehabilitation activities.

7.3.10 *Whitetopping*

IRC:SP:76 can be referred as guidelines for conventional and thin Whitetopping. Whitetopping is at present rapidly being used as maintenance and rehabilitation alternative for even urban roads which may be considered as composite pavements even though after rehabilitation. These are quite satisfactory in their performance and suitable for urban roads. **Table 7.1** gives the details reproduced from IRC:SP:76.

Table 7.1 Whitetopping

Conventional Whitetopping	Thin Whitetopping (TWT)	Ultra-Thin Whitetopping (UTWT)
• A PCC overlay of 200 mm thick or more (on the top of existing bituminous layer). • Designed and constructed without consideration of any bond between the concrete layer and underlying bituminous layer. • Designed and constructed like a new rigid pavement without assuming any composite action. • It treats the existing bituminous surface as a sub-base like Dry Lean Concrete (DLC). • Existing bituminous surface does not matter significantly, except that bituminous surface should not suffer from any isolated damages like subsidence or material related problems.	• A PCC overlay of thickness greater than 100 mm and less than 200 mm. • The bond between the overlaid PCC and underlying bituminous layer is often a consideration but it is not mandatory. • Bonding consideration may be ignored in the design. • High strength concrete with fibres is commonly used. • Joints are at shorter spacing of 0.6 to 1.25 m.	• A PCC overlay of thickness equal to 100 mm. Thickness less than 100 mm generally not recommended for Indian conditions. • Bonding between underlying bituminous layer and overlaid PCC layer is mandatory. • Milling the existing bituminous surface to an average depth of 25 mm is normally used to provide the bonding at the interface between the existing bituminous surface and PCC overlay. • Such bonding can be provided by some other methods also, but milling is considered desirable because effective bond between the existing and overlaid surface is absolutely essential for better performance. • High strength concrete with fibres is normally provided with closely spaced joints (at interval of 0.6 to 1.25 m). • It can be considered for colony internal roads where traffic is restricted and controlled and good quality control is exercised during construction.

For all kinds of Whitetopping, continuity of the subgrade/sub-base support is to be ensured. Whitetopping should not be done at locations where availability of continuity of support is in doubt. The condition of the exiting bituminous surface should be sound and free from wide cracks, material related distresses, isolated subgrade related problems.

7.3.11 *Evaluation of Existing Pavement for Whitetopping*

The evaluation of the existing pavement is an essential part of any overlay design including conventional Whitetopping. Field evaluation typically consists of a visual distress survey, deflection testing Benkelman Beam or Falling Weight Deflectometer (FWD) and coring. Foundation support value i.e. modulus of subgrade reaction (k value) is the key parameter for thickness design. The subgrade support value (k) for the existing bituminous surface can be calculated from the resilient modulus (MR). Values of k to be used can be taken from deflection test on the existing bituminous surface or by determining k value from load test on the subgrade and thereafter using correlation charts. Any other suitable method may also be adopted connecting k value of the subgrade to the modified k value of bituminous sub-base.

For assessing the condition of existing pavement, following information should also be collected:

- Type and thickness of the existing layers by taking cores or trial pits and collection of soil samples
- Type and extent of distresses
- Restriction on Finished Road Level (FRL)
- Width of existing pavement and proposed concrete overlay
- Presence of treacherous soil like Black Cotton soil
- Drainage condition, drainage requirements and sub-surface drainage
- Traffic survey data

For thickness design, design procedures, steps of construction and all other design factors for all three types of Whitetopping, IRC:SP:76 should be followed.

B. CONSTRUCTION

7.4 Specifications

For construction of pavements, MoRTH Specifications for Road and Bridge Works published by the IRC should be applicable.

7.5 Materials

Roads are composed of various conglomerations of materials. The materials, their associated properties, and their interactions determine the properties of the resultant pavement strength. The following road materials are being used normally in the construction of road pavements:

1) **Soil:** Major amount of soil is being used generally for embankment and for subgrade.
2) **Water:** Mostly used for mixing materials and curing of concrete. It should be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful in road layers and also finished concrete. It should meet the requirements

stipulated in IS 456. Potable water is generally considered satisfactory for works and also concrete curing.

3) **Aggregates (natural, artificial):** Aggregates are being used for different pavement layers viz. sub-base course, base course and in surface course which includes both bituminous and concrete pavements. The aggregates may be natural or artificial.

4) **Bituminous binding materials:** These are bitumen, tar, emulsion or cutbacks and also modified bituminous binders (polymer modified, rubber modified etc.) including foam bitumen.

5) **Bituminous mixes:** It is a combination of different types of aggregates, different sizes of aggregates and bitumen or different types of bituminous binders.

6) **Recycled materials:** The existing pavement materials can be recycled and reused with certain modifications. It can be bituminous materials that can be recycled, so also concrete pavements that can be recycled.

7) **Cement Concrete:** These are having combination of aggregate, sand and steel. The layers are known as plain, reinforced and pre-stressed cement concrete.

8) **Steel:** Generally used in rigid pavements. These shall conform to the requirements of IS 432, and IS 1786 as relevant. The dowel bars shall conform to Grade S 240 (with yield strenth 240 MPa) and tie bars (deformed/plain) to Grade Fe 500 deformed steel bars as per IS 1786/IS 432. Tie bars may be plain or deformed. If steel mesh is used, it shall conform to IS 1566. The steel shall be coated with epoxy paint for protection against corrosion, wherever required.

9) **Stabilized materials:** Especially used for sub-grade, sub-base and base course layers.

10) **Geosynthetics:** There are many types of geosynthetic materials used for specific purposes such as geomembranes, geocells, geogrid, etc.

7.6 Materials for Non-Motorised Vehicle (NMV) Lane

The riding materials for non-motorized vehicular lanes are bitumen, concrete, interlocking tiles, pavers, granite, stones, etc. and these could be used as a surface material for cycle tracks. The materials used for construction of cycle tracks should meet the requirements of being theoretically sound, validated experimentally and capable of reasonable testing and comparison.

The materials should also have the desired level of workability, economy, strength, durability, volume stability; wear resistance and impermeability. Usually it could be selected between materials for closed surfacing and open surfacing on the basis of cost, maintenance and repair work.

7.7 Recycling of Bituminous Pavements

Recycling of pavement is the process in which the existing pavement materials are reclaimed and reused after reprocessing for either (a) resurfacing, or (b) repaving, or (c) reconstruction of pavement depending upon the condition of the existing pavement, the nature of the reclaimed materials, the method of reprocessing, and the treatment that the pavement requires. The reclaiming and reprocessing of pavement materials involve both design (how the pavement should be designed using reclaimed materials with the given properties) and technology (the methods to reclaim and reprocess, equipment, knowhow and quality) issues. Once both the issues are satisfactorily handled, there should be evidence of good performance of the recycled pavements in terms of strength, durability, and serviceability. If the three factors (design, technology and performance) combine, recycling of pavements is environmentally and economically better option for pavement repair, rehabilitation or reconstruction compared to one which uses fresh or virgin materials.

The reclaimed materials usually have lot of variability in terms of aggregate gradation and binder content depending upon the location they come from (i.e. the project site and/or stockpiles), the layers they are drawn from (surfacing, bituminous base, or the granular bases), the method used for reclaiming (milling, ripping, breaking). This variability, which is required to be accounted for in designing a mix of uniform quality meeting the standards, is the designer's nightmare. The complete technology requires consideration and provision of all the processes, viz. reclamation of the pavement materials (milling, ripping, breaking) handling the reclaimed materials (in-place or off site), the processing of the reclaimed materials (to achieve the design gradation including by adding fresh aggregates and to produce the new mix with the graded aggregates including by adding fresh binder) and construction. There are essentially two types of recycling technology, viz. (1) In-place and (2) In-plant, each having two variants, viz., (a) Cold and (b) Hot. Cold recycling technology has three options, viz., (i) Foam bitumen, ii) Emulsion, (iii) Stabilization. Hot technology has two options depending upon the manner of reclamation by (i) hot process, or (ii) cold process. **Fig. 7.5** presents the overview of reclamation and recycling. IRC:120 'Recommended Practice for Recycling of Bituminous Pavements', deals with the practice which includes quality control for recycling of bituminous pavements which should be followed for application.

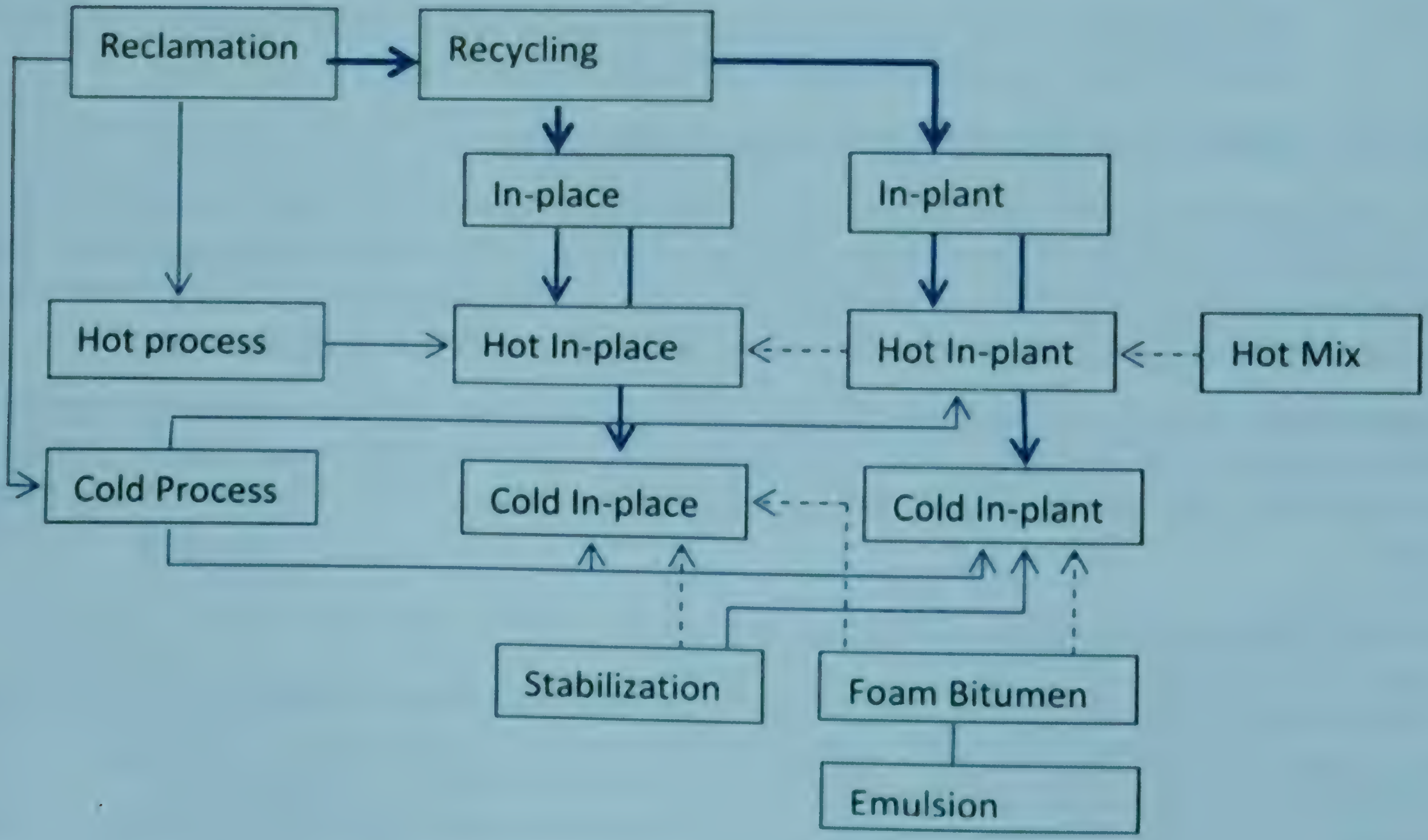


Fig. 7.5 Overview of Reclamation and Recycling

The five recycling options which would be suitable in different situations are given in **Table 7.2**.

Table 7.2 Recycling Options

Defects/Deficiencies	**Preferable Recycling Options**				
		HIR	**HIP**	**CIR**	**CIP**
Serviceability of pavement and extent of defects	High Severity defects no structural deficiencies	Y	N	Y	N
	High Severity defects extending up to bituminous bases	N	Y	N	Y
	High Severity defects extending up granular bases	-	-	Y*	-
Structural strength	Only resurfacing	Y	N	Y	N
	Resurfacing with overlay	N	Y	N	Y

Source IRC:120: HIR: Hot In-place recycling HIP: Hot In-plant recycling CIR: Cold In-place recycling CIP: Cold In-plant recycling, *: Full Depth Recycling

The maximum recommended depths of recycling within recycling options are 50 mm for HIR, 100 mm for HIP, 75 mm for CIR and 100 mm for CIP. In case the thickness required as per design is more, the balance thickness should be made up by hot mix materials, the recycled layer acting as levelling course.

C. MAINTENANCE

7.8 Need for Pavement Maintenance

i) Pavement maintenance serves the following objectives:

a) Reduces rate of deterioration of pavement which helps in postponing investments in periodic maintenance and reconstruction and prolonging the life of the pavement to serve its intended purpose.

b) Reduces vehicle operation cost for road users as also pollution from motorized vehicles.

c) Improves energy efficiency of motorised vehicles.

d) Enhances road safety and reduces traffic hazards.

e) Keeps roads traffic worthy.

It needs to be borne in mind that off-carriageway maintenance such as maintenance of berms, verges and drains also has profound effect on pavement maintenance and needs equal attention of the road authorities. Steps need to be taken for effective dust control/removal on urban roads and streets. Vacuum machines are now available in the market to facilitate this task.

ii) For roads in urban areas, pavement maintenance needs to include not only the main carriageway but also footpaths, cycle tracks, service roads, etc.

iii) Pavement maintenance may be divided into the following types for the purpose of preparing Annual Maintenance Plans, seeking budget allocations and execution of maintenance activities:

a) Routine Maintenance: This covers items such as repairing of potholes, cracks, patch work, etc. which are required to be carried out regularly throughout the year. Attention should also be paid to cleaning and clearing of side drains and maintenance of camber/cross fall on carriageway and shoulders. Pavement markings should also remain visible during the maintenance period to guide the road users and improve road safety. Special attention should be paid immediately after rains.

b) Preventive Maintenance: The preventive maintenance is performed to improve or extend the functional life of pavement surface while in good and fair condition. This helps in postponing the need for periodic maintenance and rehabilitation.

c) Periodic Maintenance: This includes applying a renewal coat, which is required to be carried out periodically, based on condition and performance assessment of pavement, depending upon category of road, traffic, and climatic conditions.

iv) Routine maintenance of pavement and off-carriageway road assets does not admit of any tolerance on the part of road authorities and must be a first charge on the maintenance budget.

7.9 Planning for Maintenance

A systematic and scientific evaluation is necessary for maintenance and rehabilitation of pavements. The pavement condition is generally evaluated by measuring the deflection, roughness, surface distress and surface friction. Performance evaluation is directed primarily to how well the pavement is providing serviceability to the user, what level of surface distress exists, the existing structural adequacy, and the level of safety in terms of surface friction.

7.9.1 *Modes of Deterioration of Pavements and Level of Assessment for Maintenance*

Each road pavement, independent of its type and materials applied, is subjected to certain traffic loads and environmental factors. It results in various types of deterioration under in-service conditions. Modes of deterioration and the level of susceptibility of the pavement to various deteriorating factors depend on the type of pavement and materials applied. Generally, deterioration of the pavement is considered in two modes (i) surface, and (ii) structure. **Box 7.1** gives the modes of deterioration.

In the case of cement concrete pavements, the following modes of deterioration are considered. Surface deterioration is a defect of pavement surface and improvement may consist of maintenance of the surface layers only. Structural deterioration is a defect of the whole structure requiring extensive rehabilitation/resurfacing of pavement.

7.9.2 *Assessment of Maintenance Needs for Bituminous Roads*

The IRC Code of Practice for Maintenance of Bituminous Road Surfaces (IRC:82) provides insight about assessing the maintenance requirement after rating the surface condition of the pavement. The complete methodology and rating have been detailed in the code and should be referred for its application. A typical pavement distress based rating for flexible pavements of urban roads given in IRC:82 is reproduced in **Table 7.3**.

Table 7.3 Pavement Distress Based Rating for Urban Roads

Defect	Range of Distress		
Cracking (%)	>15	5 - 15	<15
Ravelling (%)	>10	5 - 10	<5
Potholes (%)	>0.5	>0 and ≤0.5	Nil (0)
Settlement (%)	>5	1 - 5	<1
Rut depth (mm) using 3 m straight edge	>10	5 - 10	<5
Rating	1	1.1 - 2	2.1 - 3
Condition	Poor	Fair	Good

Box 7.1 Modes of Pavement Deterioration

Bituminous Pavements

- Surface deterioration
    - ➢ Decrease in friction (polishing)
    - ➢ Fatigue cracking
    - ➢ Surface cracking
    - ➢ Ravelling (stripping)
    - ➢ Pothole
- Structural deterioration
    - ➢ Permanent deformation of sub- grade/ settlement
    - ➢ Rutting
    - ➢ Subgrade failure

Cement Concrete Pavements

- Surface deterioration
    - ➢ Decrease in friction (polishing)
    - ➢ Surface cracking
    - ➢ Delamination
    - ➢ Spalling/ravelling of joint saw cuts
- Structural deterioration
    - ➢ Full depth cracking (bottom-up or top-down)
    - ➢ Curling and warping of slabs
    - ➢ Pumping

In some situations, there is likelihood of a particular distress falling in one rating category, say good, while some other distress falls in a different rating category, say fair or poor. For details in overall rating in such circumstances refer Appendix-4 of IRC:82.

Apart from visual surveys, functional evaluation of pavement based on riding quality (i.e. road roughness), deflection and skid resistance should also form the basis for taking maintenance decisions in case of urban roads. Skid resistance is an important parameter from the angle of ensuring enhanced safe movement of vehicles, especially during wet weather conditions. Lower skid resistance invites safety hazards and would require immediate attention. The serviceability indicators for maintenance are given in **Table 7.4**.

Table 7.4 Serviceability Indicators for Urban Roads

S. No.	Serviceability Indicator	Level 1 (Good)	Level 2 (Fair)	Level 3 (Poor)
1.	Roughness (Max. permissible)	1800 mm/km	2600 mm/km	3400 mm/km
2.	Skid Resistance (Skid number by ASTM-274) Minimum desirable	65 SN	55 SN	45 SN

Note: Level 1 is expected to match with new pavement condition, level 2 is the in-service minimum desirable level and level 3 is the warrant for intervention to restore the pavement condition to level 1.

It will be cost-effective to go in for preventing maintenance of those sections of Arterial and Sub-arterial roads as have reached Level 2 (Fair).

Maximum permissible values for roughness with respect to different surface layer types and category of roads, IRC:SP:16 should be followed.

7.9.3 *Assessment of Concrete Maintenance Needs*

The evaluation of the existing concrete pavement condition is an important part of the process of assessing the maintenance needs. IRC:SP:83 should be referred for details. The maintenance strategy will be determined according to the level of deterioration. The characterization of the condition of the existing pavement depends largely on the types of treatments to be considered. Characterization includes the types of distress, width and depth of crack/defect, percentage area affected; joint defects etc. (refer **Table 4.5** of IRC:SP:83). Different evaluation tests and procedures are available for a complete and comprehensive evaluation of the existing pavement condition.

The maintenance needs should be assessed every year as part of the planning of the road maintenance program. This should be done on the basis of condition surveys which can take various forms such as:

a) visual rating
b) profile/roughness measurements, by profilograph and Bump Integrator (BI),
c) deflection tests, by Falling Weight Deflectometer (FWD),
d) friction/skid resistance tests by sand patch, British Pendulum and Mu-meter,
e) drainage condition survey.

Additional testing and measurement will be required to collect data specific to the needs identified during the overall condition survey based on repair/rehabilitation alternatives to be considered in the maintenance program. For example, concrete material evaluation, base/sub-base and sub-grade testing and drainage condition surveys. The frequency of such additional testing will depend on the age and extent of damage recorded in the overall condition survey.

7.10 Devices for Measuring Surface Deflection

There are different types of devices available for measuring the surface deflection of a pavement, such as Falling Weight Deflectometer (FWD), Benkelman Beam Deflection (BBD), Dynaflect, Loadman etc. FWD and BBD are quite common in use for evaluation of urban roads. There are two IRC Guidelines used for structural evaluation of urban roads viz. IRC:115 (for FWD) and IRC:81 (for BBD).

7.11 Road Asset Management System and Coordination with Utility Agencies

Roads are an important asset for any urban local body. An innovative system that enables the road agency to manage road related information is important for efficient delivery of service to the public. It helps the road agency to make decisions about prioritization of roads, repair and maintenance.

The laying and maintenance of important urban utilities such as water supply, sewer, electrical, telephone, optical fibre cables, piped gas, storm water form an integral part of the road agency work. Because of mixed land use pattern in most cities, it is difficult to realistically assess the need for future utilities and their augmentation. Due to the advent of advanced communication technologies like 4G, 5G, the roads are frequently required to be dug to house these utilities under the road.

The laying of separate RCC pipes and ducts is recommended to take care of provision for future utilities. The detailed guidelines are given in IRC:98 "Guidelines on Accommodation of Utility Services on Roads in Urban Areas". Many cities lack plans, drawings detailing the information of the existing utilities underneath the road. Even the information regarding newly laid utilities is not maintained properly. This creates a chaotic situation in most urban areas due to frequent digging of roads and patching of roads.

The utility related problems can be partially addressed by implementation of software based systems termed as Road Information System (RIS) or Road Asset Management System (RAMS). An RIS or RAMS is a technical or operational method for managing all road related information along with the underground utility services. The RAMS can host variety of data related to road and bridge inventory, traffic data, road condition, utility services, trees, roadside advertisements, road signages, vendors etc. The Road Asset Management System based on a Geographic Information System (GIS) platform further enhances the capability of the road agency in making informed decisions by observing different road network condition and design parameters on a colour coded road network map. It also enables consideration and visualization of the impact of fund allocation decision for any particular road on the entire road network. The GIS enabled capability helps in sharing valuable construction and project information with other Municipal Utility Departments to coordinate activities and minimize frequent digging and subsequent damage to roads. The GIS based systems are managed by Central Coordination Cell established by the Municipal agencies especially for inter and intra department agencies.

The base data in RAMS is collected using Automated Data Collection vehicles equipped with high resolution cameras, DGPS equipment and laser profilometers. The inventory and utility data is also collected by a crew using hand held Global Positioning System (GPS) enabled tabs and advanced equipment like Ground penetrating radars or taking excavated cross cuts along the road section.

The important requirement for successful implementation of the RAMS system is the continuous updating of the asset data. Some cities have already mapped the utility services on GIS platform for information sharing between various internal and external agencies involved in the utility and road works. The external agencies especially the Electrical Utility Companies, OFC cable companies, Telephone/Internet Service providers, pipes gas line providers may be required to submit their data to the municipal authorities in GIS compatible format before undertaking any excavation work on the road. Additionally, the contractor's payment for any utility laying, maintenance and road construction/maintenance work may be released only after seeking the "No Objection Certificate" from the Central Coordination Cell ensuring the updating of the work data to the system. This will help in meeting the requirements of Utility Agencies and at the same time protecting the existing road assets from untimely and premature deterioration.

CHAPTER 8

DRAINAGE

8.1 Introduction

Drainage and life of pavement are interrelated. Longevity of pavement depends on proper drainage and its up keep. In urban areas, this is an important element in overall planning of cities. Water bodies in and around urban settlements must be harnessed and protected. It is an integral part of road network for disposal of surface and sub-surface water. Structural integrity of road depends on effective and efficient disposal of storm water. This chapter draws heavily from IRC document on Urban Drainage IRC:SP:50.

The urban drainage can be divided into the following four activities:

1. Road surface drainage
2. Sub soil drainage
3. Disposal of storm water
4. Infiltration into ground for recharging of ground water table

8.2 Road Surface Drainage

Traffic safety and service condition of road pavement can be maintained only if effective road drainage exists. Water on the pavement can reduce skid resistance, can interrupt traffic, and reduce visibility due to splash and spray. Increase potential for hydroplaning and cause difficulty in driving the vehicles. The surface drainage comprises, flow in drains and capacity of inlets. Design of these elements depends on storm frequency and allowable spread of storm water on the pavement surface.

The rain water travels as unsteady non-uniform sheet flow from middle of pavement to edge of pavement. Factors influencing the depth of water on pavement are the flow of path length, surface texture, surface slope and rainfall intensity. The following drainage elements are essential.

i. **Longitudinal gradient of pavement:** Longitudinal gradients shall not be less than 0.5% for pavements for satisfactory drainage. A minimum longitudinal gradient of 0.3% is necessary to facilitate flow of water inside drains.

Transverse gradient of pavement/camber: For quick disposal of precipitation on the road surface, it would be necessary that water has to travel least distance through reasonably steep cross slope. The transverse gradients are a compromise between the need for reasonably steep gradient for drainage and relatively flat gradient for driver comfort and safety. Judicious balance between steep and flat gradient is required and a cross between, 2% in areas with normal rainfall and 2.5% in areas with intense rainfall can be adopted for effective drainage.

Hydro planning: When the water level rises on the road, the drainage capacity of tyre tread pattern and pavement surface is exceeded and water begins to build up in front of tyre. This phenomenon is called hydro planning. A water wedge gets created which produces hydro dynamic force which can lift the tyre off the pavement surface, the tyre loses its tractability resulting in control of vehicle.

ii. **Shoulder drainage and footpath drainage:** For paved footpaths, a cross fall of 3-4% should be adopted sloping away from the carriageway. For verges and unpaved areas, cross fall of 4-6% may be adopted. For shoulders along uncurbed pavement, the cross fall should be at least 0.5% steeper than that of pavements subject to minimum values given below.

WBM surface – 3%

Gravel surface – 4%

Earth surface – 5%

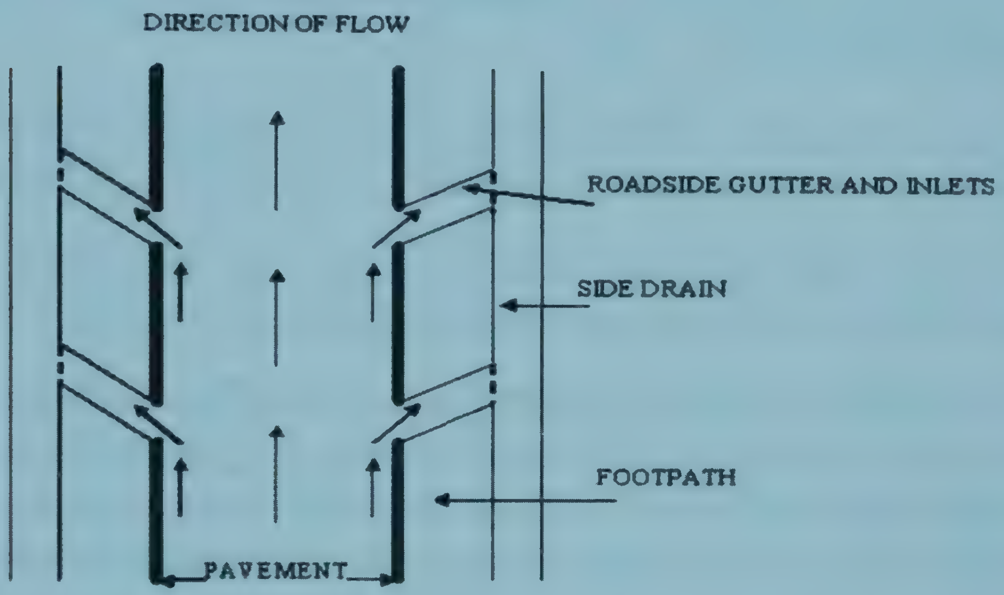


Fig. 8.1 Inclination of Roadside Gutter and Inlets with respect to Flow in Pavement

8.3 Appurtenants for discharge of Storm Water Drains

- i) Tertiary drain/Road side drain/gutter
- ii) Shoulder drain/Inlets

i) The road side drains can be constructed out of any locally available materials like bricks, size stones, solid blocks, RCC- where slender walls are required and combined utility ducts can be provided. Weep holes at regular intervals shall be provided in drains to drain the sub grade water from below the pavement. The road side drain/ gutter shall be a minimum of 600 mm wide with internal smooth finish and shall have a minimum transverse slope of 1 to 6. The longitudinal slope of road side gutter and inlets is guided by road gradient.

ii) The shoulder drain/inlet is an important and essential for storm water draining. The appurtenant structures are important and essential for efficient functioning of storm water drainage. These are devices meant for admitting the surface run- off to the drain and constitute an important part of the system. Their location and design shall therefore be given careful consideration. Inlets (shown in **Fig. 8.1**) are typically located in gutter sections, paved medians, road side and median ditches. Storm water inlets can be categorised as;

1) Grate inlets
2) Kerb opening inlets
3) Slotted inlets
4) Combination inlets

5) Manholes
6) Bell mouth inlet

Refer IRC:SP:50 for different arrangements of shoulder drains.

The alignment of road side gutter and inlets underneath side walk shall be in the direction of flow of water during storm for efficient discharge as shown in **Fig. 8.1.**

The shoulder drains shall generally be spaced at intervals up-to 50m in level ground and at closer intervals up-to 5m in saddle areas and junctions. The shoulder drains in high intensity traffic areas shall be up-to 3m. The shoulder drains can also be of NP-3 pipes of circular, horse shoe, elliptical shapes.

The road side drains can efficiently function only in case the shoulder drains perform. Clogged inlets make surface water remain on surface resulting in damage to pavement during rains.

The median walls shall be taken for considerable depth up-to sub grade level of road so that water does not seep into base or sub base layers of pavement.

In locations where unicamber is provided, necessary opening shall be provided in the median for smooth passage of water from one lane to the other and onwards to side drain **Fig. 8.2**. The determination of median crossings for drainage requires good engineering judgment. These crossings are governed by hydraulic as well as non-hydraulic considerations.

On curves, the median acts as an obstruction to flow of storm water towards inside of curve leading to flooding of other carriageway. A median opening shall be provided from outer to inner edge as shown in **Fig. 8.2** and **Photo 8.1.**

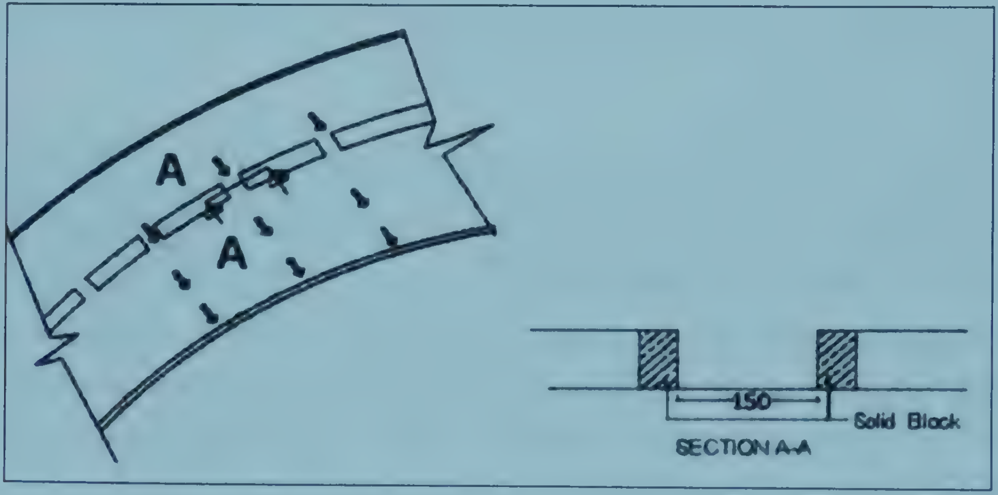


Fig. 8.2 Median Opening up to Two Lane in each Direction

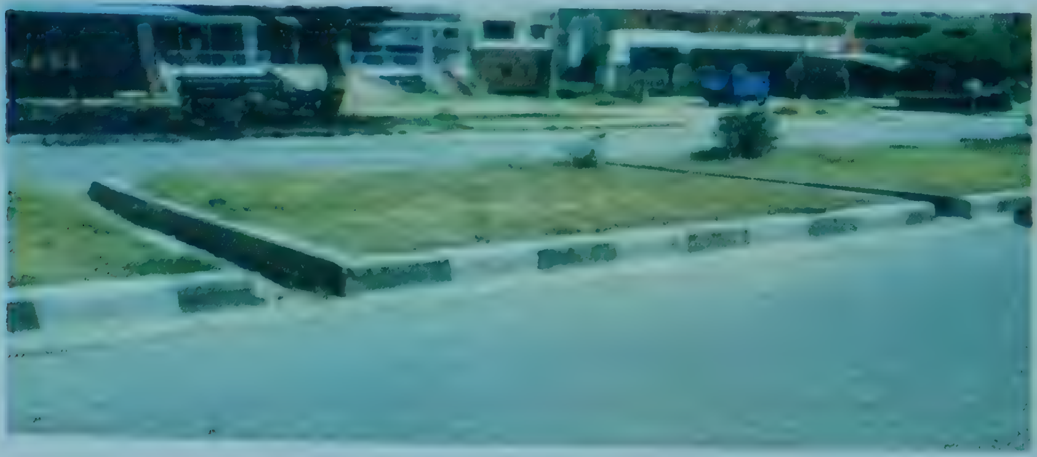


Photo 8.1 Median Opening up to Two Lanes in each Direction

The provision of median opening at super elevations and curves in divided carriageway shall be for and up to two lanes as shown in **Fig. 8.2**. When the carriageway is three lanes or more, then a drain shall be provided below the median and in turn connected to lower level drain by a minimum 600 dia NP-3 pipes. See **Fig. 8.3**.

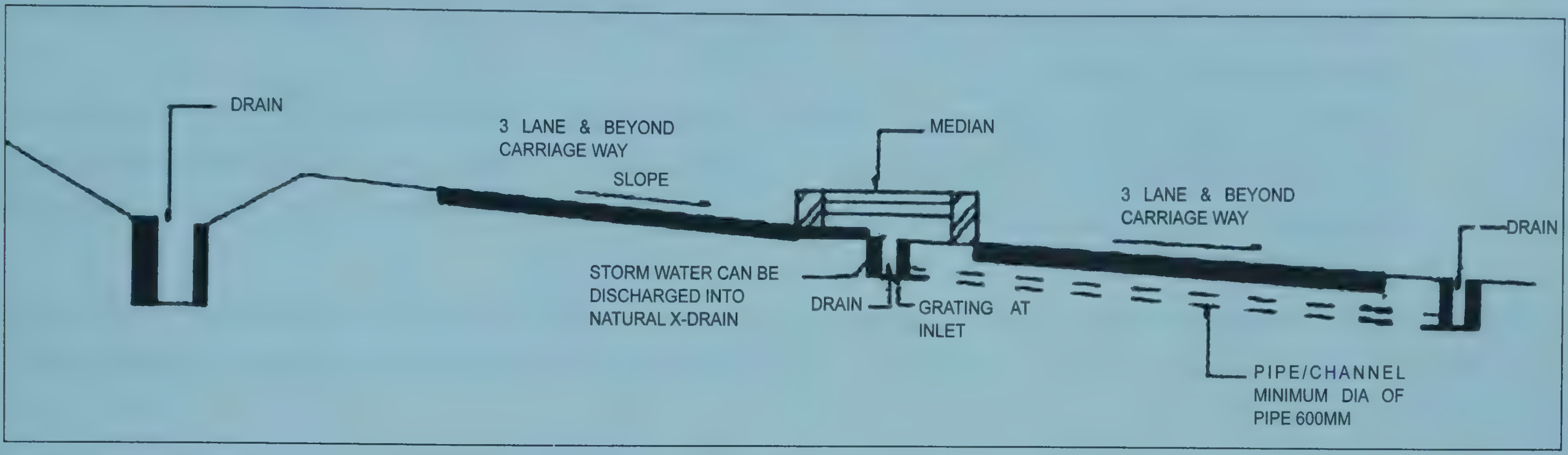

DRAIN
3 LANE & BEYOND CARRIAGE WAY
SLOPE
MEDIAN
3 LANE & BEYOND CARRIAGE WAY
DRAIN
STORM WATER CAN BE DISCHARGED INTO NATURAL X-DRAIN
DRAIN
GRATING AT INLET
PIPE/CHANNEL MINIMUM DIA OF PIPE 600MM

Fig. 8.3 Drainage Arrangement at Medians (for three lanes or more in each direction)

iii) **Bridge deck drainage;** Bridge deck drainage will be relatively less efficient than road drainage due to flatter cross slopes. The side drain flow from roadways shall be intersected and diverted before it reaches the bridge. Run off from the bridge deck shall be collected immediately through drainage spouts with gratings after it flows into subsequent pavement section where larger grates and inlet structures are provided for effective end point drainage. Any ponding of collected water due to defective cross slopes and disposal system will result in splashing of collected water on the moving vehicles resulting in reduced visibility and increased accident hazards. Each pier shall have a drainage disposal pipe designed for the area of disposal for immediate discharge of rainwater from bridge deck.

iv) **Drainage of high embankments:** In high embankments and approaches to the bridges, rain water is collected in small manageable quantities through longitudinal kerb channel and brought down through steeped chutes without damage. The chutes may be lined with cement concrete on stable supports at an interval of 10-15m depending upon the rainfall and width of carriageway. Stepped out fall may also be used in place of plain chutes. For details refer IRC:SP:50.

8.4 Storm Water Management and Appurtenances

The storm water from shoulder drains/gutters will flow on to the secondary drains and on to primary drains which are valleys/rivers.

Classification of urban storm water drains

Drainage in urban context is classified as;

a) Primary drains
b) Secondary drains
c) Road side drains/gutters (also known as Tertiary Drains)

a) **Primary drains:** These are natural drainage systems at the end point of disposal, connecting series of major water bodies up to disposal in a particular catchment area.

This drain receives water from one or more watershed regions through secondary drainage network, tertiary drainage network directly from roadside drains.

b) **Secondary drains:** These are natural or manmade network drains connecting primary drains or a water body. It originates from a particular watershed region and receives water from one or more micro watershed regions through tertiary drainage network or from roadside drains.

c) **Tertiary drainage:** These are natural or manmade network of drains connecting to secondary drains or a water body. It originates from network of roadside drains and receives water from micro watershed regions directly or through road side drains or in combination of both.

A master plan of existing network of primary and secondary drains shall be prepared for every city or town for future guidance and to check any encroachment or diversion of drains by individuals particularly in new lay outs.

Urbanization has resulted in large scale construction activities primarily paved roads, lined drains which were earlier acting as pervious natural surfaces. This has caused increased volume of run-off resulting in lesser ground water storage. In order to optimize the run off of storm water from initial point to the final disposal point, a well thought out percolation mechanism all along the route should be in place so that the final disposal volume will be the least possible, in addition to recharging of ground water. **Fig. 8.4** gives broader view of storm water management.

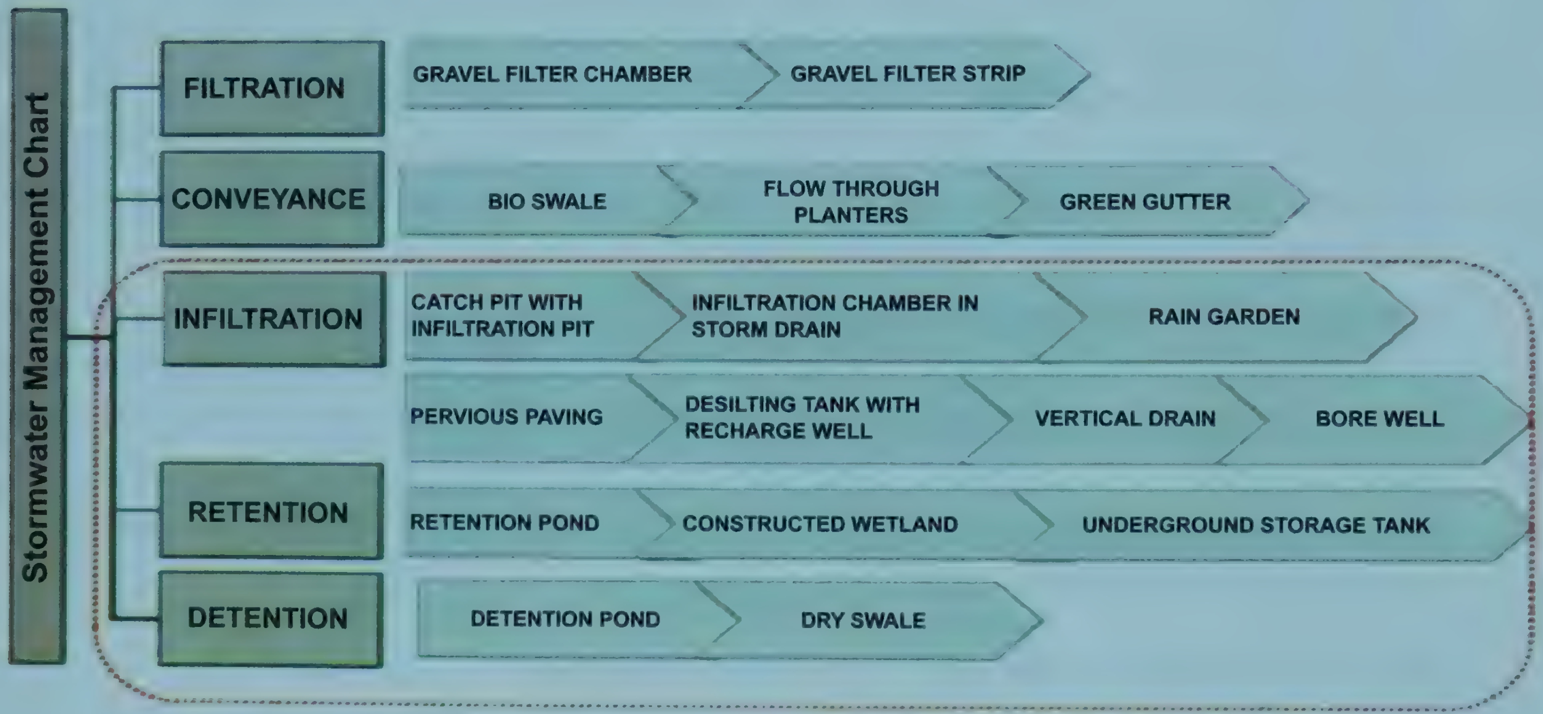

Stormwater Management Chart
FILTRATION
GRAVEL FILTER CHAMBER
GRAVEL FILTER STRIP
CONVEYANCE
BIO SWALE
FLOW THROUGH PLANTERS
GREEN GUTTER
INFILTRATION
CATCH PIT WITH INFILTRATION PIT
INFILTRATION CHAMBER IN STORM DRAIN
RAIN GARDEN
PERVIOUS PAVING
DESILTING TANK WITH RECHARGE WELL
VERTICAL DRAIN
BORE WELL
RETENTION
RETENTION POND
CONSTRUCTED WETLAND
UNDERGROUND STORAGE TANK
DETENTION
DETENTION POND
DRY SWALE

Fig. 8.4 Storm Water Management Chart

8.4.1 *Infiltration*

In the present scenario of depleting ground water, all storm water drains should be utilized for the benefit of raising existing ground water table. The existing drainage cross sections be redesigned in such a way that storm water starts infiltration into ground at street level drain itself which is the first point of collection and continued through tertiary drains, secondary drains and finally to primary drains. In view of ground water depletion beyond 250m in certain urban areas, all new drains and retrofitted drains shall have bottom infiltration pit as in **Fig. 8.5**, intermittently throughout their length for all types of drains.

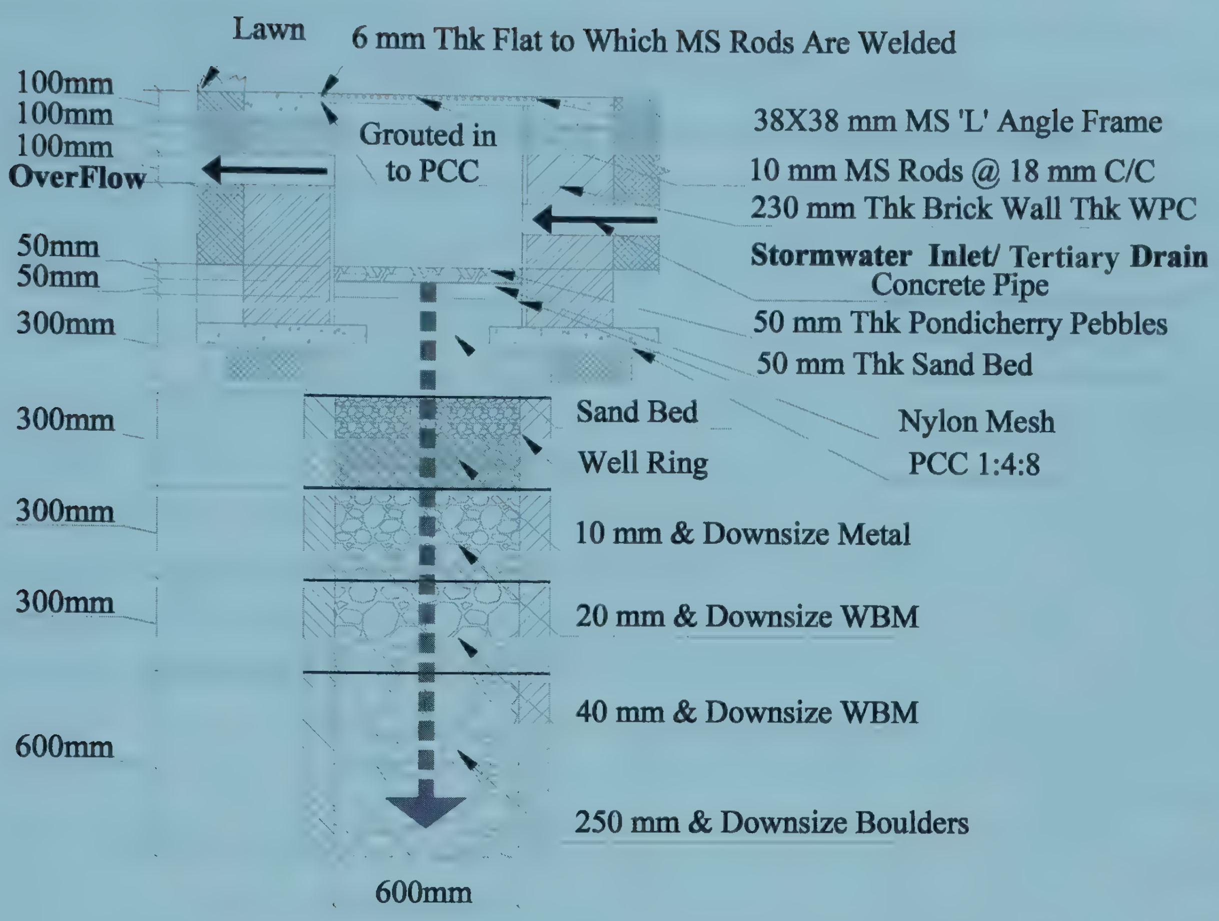

Lawn
6 mm Thk Flat to Which MS Rods Are Welded
100mm
100mm
100mm
OverFlow
Grouted in to PCC
38X38 mm MS 'L' Angle Frame
10 mm MS Rods @ 18 mm C/C
230 mm Thk Brick Wall Thk WPC
Stormwater Inlet/ Tertiary Drain
Concrete Pipe
50mm
50mm
300mm
50 mm Thk Pondicherry Pebbles
50 mm Thk Sand Bed
300mm
Sand Bed
Nylon Mesh
Well Ring
PCC 1:4:8
300mm
10 mm & Downsize Metal
300mm
20 mm & Downsize WBM
40 mm & Downsize WBM
600mm
250 mm & Downsize Boulders
600mm

Fig. 8.5 Typical Selection of Infiltration Pit

8.4.2 *Detention and Retention Facilities*

Detention and retention facilities have been provided wherever land is available and in areas prone to flooding during monsoon and also to reduce the cost of larger section of storm water drainage system by reducing the size required for downstream conveying systems. This can also provide aesthetic value to the surrounding area and recharging of ground water.

For details, refer IRC:SP:50.

8.4.3 *Functional Requirements of Drains*

The functional requirement of any drainage system will be its efficient disposal mechanism. Drainage water can be disposed of;

- a) Over the surface
- b) In open channels
- c) In covered drains
- d) In flat terrain

a) Over the surface

As and when certain semi-urban areas and revenue pockets are merged into urban conglomerates, the areas would have been under developed and the roads will normally be narrow and without provision of drains. In such situations, water shall be drained through gutter into main street drainage system where the minor street meets main street.

b) **In open channels**

The open drain along road side shall preferably be at the edge of right-of-way of road, as it has dual advantage of transportation of water as well as demarcation of road property. These drains are more efficient as they carry larger discharge particularly in flood conditions when drainage is surcharged and when the shoulder drains are made functional. These drains are easier to maintain and allow for removal and disposal of silt and other solids carried by storm water.

c) **In covered drains**

Covered drains can be located at the edge of right-of-way, below footpath or even below carriageway, where the road is narrow, as in newly added areas/revenue pockets and road land is encroached, RCC box drains designed to take vehicular load may be provided in the carriageway with manholes/gratings for maintenance. Concrete pipe drains of appropriate shape as circular, elliptical, pipe arch, horse shoe can be used with closely spaced manholes, as good mechanical equipment are available for cleaning and desilting.

d) **In flat terrain**

Disposal of storm water in flat terrain is a tricky affair, as conveyance will be very slow or nil due to zero or near zero gradient. A good strategy in such situations is to increase the dimensions of drains and lead to infiltration pit (**Fig 8.5**).

8.4.4 *Disposal of Storm Water*

It is essential to dispose of rain water into one of the following natural bodies:

1) River system
2) Coastal waters
3) Flood plains
4) Water bodies and natural reservoirs
5) Underground strata

For hydraulic design of storm water drains refer IRC:SP:50

8.5 Sub surface Drainage

The sub surface water in the granular layers or in the sub grade of pavement can harm road in following ways:

i. The presence of water reduces sub-grade strength. The strength of granular sub bases/sub bases is strain dependent and poor strength in sub grade affects the performance of top layers also.

ii. Heavy wheel loads may create pulsating water pressure resulting in internal erosion and injection of materials through cracks and joints. This coupled with movement of sub soil water, changes the arrangement of fine to coarse material and aggregates in the structure resulting in weakening granular bases, cement treated bases and stabilized layers.

iii. Absorption of water in the filler material, which may not be fully non plastic, may seriously undermine the load support characteristics of the layer.

iv. Free water in bituminous pavements results in stripping of the binder leading to faster cracking and deterioration.

For design of sub surface drainage system, the source and quantum of water must be determined and the ingress of water may take place from:

- Top that is surface infiltration of water through paved or unpaved areas
- Lateral seepage through shoulders and verges
- Free water from high water table or capillary action from water table.

In most urban areas, the percentage of built up surface area is rather high and as such situations with problems of sub surface water may not be frequent unless the water table is unusually high and sub grade soil is poor from the point of view of drainage. The most efficient way of drainage of pavement course is to provide and extend a specially designed sub-base layer up-to the embankment slope space. In urban situations, this may not always be possible. In such circumstances, provision of a sub-surface drain is made. The sub base layer and the sub-surface drain should have sufficient capacity to carry the design discharge through sub-base layer, which is considered as saturated laminar flow, calculated using Darcy's law and the flow through pipes is calculated using Manning's formula. The Darcy's law gives:

$Q = KiA$

Where,

Q = Discharge in m^3/sec

K = Coefficient of permeability in m/sec

i = Hydraulic gradient

A = Cross-section area in m^2 perpendicular to the direction of flow

The sub-bases and base should have self-draining provision by extending granular drainage area layer fully over the road formation width. In addition, proper cross-fall to the drainage layer shall be provided to guard against sluggish flow. As a general rule, the lower pavement layer should be more permeable than the upper one.

8.5.1 *Drainage of Sub surface Water*

Sub surface water flow is calculated from Darcy's law. Application of theoretical modules to complex natural situations can lead to errors in estimation of quantity of flow and flow conditions. Therefore, field observations and measurement are the best guide to arrive at judicious quantities.

8.5.2 *Aggregate Filters*

A properly designed and installed aggregate filter should be able to retain soil and prevent the movement of soil particles, thus eliminating piping potential. Properly, designed aggregate filters ensure that there are no large voids within the filter and particularly at soil filter interface of a sub-surface drainage structure.

A single component aggregate filter may be used to protect relatively coarse soils whereas drainage through fine soils usually require a multi layered aggregate filter. A multi layered filter consists of a fine aggregate gradation which retains the natural soil particles at their original positions and a course of filter aggregate which prevents particles of fine aggregate filter from migrating into perforations of drainage pipe or granular water transport medium.

For details of sub-surface drainage, refer IRC:SP:50.

8.5.3 *Fabric Filters*

Filter fabrics on geo textiles are generally manufactured from poly-ethylene or poly-propylene or similar fibres, either woven or non-woven in variety. For sub soil drainage system bio-degradable fabric filters are not used as their life span is very short. Geo-textiles eliminate the need for aggregate filters. The fine pore size and high permeability of these filters are suitable for protecting broad range of soil gradations. These filters are available with variant pore sizes and permeability properties.

8.6 Disposal of Acceptable Quality of Storm Water

Under Ground Drainage lines are laid in Primary/Secondary storm water drains. The man holes of these UGD lines if raised up to full flood level will cause obstruction and in case of flooding the cover opens out and the sullage water gets mixed with storm water. Likewise, damaged joints and pipes also results in sullage water mixing with storm water. A good way to negotiate is to relocate these lines or provide cut-off drains on either side of storm water drain for carrying sullage water through pipes. The other alternative is to store the sullage water during dry weather at long intervals and treat the water by Sewage Treatment Plant.

8.7 Drainage of Storm Water in Special Locations

Special locations in urban scenario for drainage will be:

1) Flyovers and bridges
2) Foot of flyovers
3) Vehicular subways
4) Rotaries
5) Retail outlets
6) Intersections

8.7.1 *Flyovers and Bridges*

Caution shall be exercised not to allow straight drop of water from flyover to road surface which results in disruption of traffic and damage to road surface. The rain water on the flyover shall be drained by down take pipes at every pier location for effective clearance of storm water.

8.7.2 *Foot of Flyovers*

The longitudinal gradient of ramp of flyovers is usually upto 3% and the cross slope will be about 2%. Large quantity of water reaching the valley from flyover where it meets ground level road shall be provided with finger plate drain across the pavement. The valley junction shall be engineered in such a way that even below road pavement, there would be downward longitudinal gradient towards valley junction, so that entire rainwater from flyover can be efficiently discharged into the drain. Finally, it can be led to main storm water drain.

8.7.3 *Vehicular Subways*

Vehicular subways shall be planned for effective drainage at its conception stage itself. Most preferable system of drainage will be by gravity. The entire surface drain of subway shall be taken to a lowest level which shall be outside the subway and a suitable grating provided across full width of road. It shall have a disposable chamber which will collect storm water and drive it off to nearby storm water management facility. The lead of drain from underpass will have manholes at a maximum spacing of 30m. In case of wider sub base, two inlets can be provided on both ends of box approach ramps. However, the inlet gratings shall be at least 10m away from the deck.

8.7.4 *Rotaries*

Due to super elevation requirement, water from large areas flow towards centre of the rotary. Once the water is directed in the rotary, it shall be drained off efficiently to the local drainage system. Minimum size of outflow from the rotary shall be 600mm width for ease of maintenance. If the site condition permits, the outlet can be made in multiples.

8.7.5 *Retail Outlets*

Gratings shall be provided at the approaches over existing drains so that rain water from the retail outlets like gas stations will be drained off straight into the storm water drain and it will not be routed on to the pavement. This grating shall be for the full length of gas station.

8.7.6 *Intersections*

Drainage at intersections shall be well planned. Any stagnation of water at intersections would reduce the capacity of junction resulting in traffic jams and underutilization of junction. For details of storm water drainage at special locations, refer IRC:SP:50.

8.8 Ground Water Recharging

Ground water recharging needs to be viewed and implemented on high priority basis due to depletion of ground water table and presence of carcinogenic nitrates, which can pose dangerous health hazards to humans consuming ground water. Infiltration of rain water has been brought out earlier in para 8.4.1

Infiltration of rainwater, which is discharged from pavement surface can be trapped by construction of infiltration-filter median drains all along the pavement. The regular drains shall be located adjacent to infiltration drains to facilitate water from pavement to enter infiltration drains and in case of excess water will flow to regular drains.

French drains are quite popular in some countries. Deep bore-wells can also be provided in tertiary and secondary drains more so in valley points for infiltration of water into the ground. The most effective ground water recharging can be carried out while undertaking construction of new roads. This system shall be part and parcel during planning of new layouts. Recent development in recharging is porous pavements, being implemented in other countries. The same can be introduced as pilot projects before regular implementation, in our cities.

8.9 Maintenance of Drains

The drainage system is at its best when it is maintained properly as designed. For this purpose, it is necessary that the drains keep the shape and slope as per the design during their life time. It is also necessary to ensure that the drains retain their full cross section particularly during monsoons. The system of maintenance can be classified into following categories.

- Continuous regular maintenance
- Periodical maintenance
- Special maintenance

8.10 Broad Checklist for Maintenance of Drains

- Pavement crown or cross slope is maintained in design profile conducive to quick drainage.
- Road shoulders are clear and dressed for efficient clear off.
- Check whether there is need for new side drain chutes in high embankment.
- The kerb channel is clean and slopes towards the inlets.
- The drain is desilted before rains, all manholes and grit chambers are cleaned.
- Inspection after heavy rains is required to find out the deficiencies in the system, and reporting unsatisfactory performance and also suggesting rectification measure.
- Preparing plans for maintenance interventions
- Gratings/metallic covers should be checked before monsoon for repair or replacement if any.
- Re-locate obstructions like utilities in and across drains.
- Discourage and enforce street, house sweeping debris being dumped into open drains or gutter openings.

It is a common practice that all drains are desilted thoroughly before onset of monsoons. All kutcha side drains shall be dressed and deepened before monsoon. It is also essential that all the drains are in state of good condition and works regarding reshaping or profile correction wherever required completed well before the onset of monsoon. For pipe drains, suitable measures shall be undertaken for desilting purposes. For details of maintenance of drains, refer IRC:SP:50.

8.11 Geographical Information System – Master plan

It is desirable that a master plan is prepared on GIS (Geographical Information System) platform based on the analysis of drainage patterns, hydrological mapping, topography and open spaces of the city. It will help in identifying watersheds, critical aquifer recharge zones, ecologically sensitive riparian zones and other green areas of the city that need to be preserved for their role in sustainable urban drainage system. In addition, a master plan may be prepared for storm water drains in every city and town indicating type of drains, cross sectional area and also rehabilitation mentioning the return period. Some of the cities have already embarked upon preparing such master plans.

Several urban local bodies have already prepared and updated road history register in GIS format, showing periodical overlays, repairs carried out to the pavements etc, and same register shall be used for updating the details of all drains.

CHAPTER 9

BRIDGES AND CULVERTS

9.1 Introduction

This chapter covers broad features of design, construction and maintenance of bridges and culverts. The key aspects required to be considered in the Planning, Design, Construction and Maintenance of bridges and culverts has been covered. The requirements and provisions may be followed as per the relevant IRC Codes. The support of domain experts in bridge structures should be sought in design and preparation of DPRs for bridges.

9.2 Classification

Bridges and culverts are classified based on their overall length.

a) Culvert - length less than 6m between inner faces of dirt walls.
b) Minor bridge - length from 6m to 60m between inner faces of dirt walls
c) Major bridge - length exceeding 60m between inner faces of dirt walls

9.3 Geophysical Investigations

For geophysical methods of investigation, refer IRC:123, wherein details about possibilities of visualizing inside the earth beyond 100m, location of sloped rock profiles, large empty cavities, water levels, densities and such similar geophysical properties of the location are briefly described. Geotechnical Investigations can, therefore, be suitably modified to locate the boreholes so as to optimize the cost of investigations.

9.4 General Design Requirement

9.4.1 *Culverts*

These can be of following types:

a) RCC Hume pipes/Alternative of pipes laid in concrete casing all around
b) RCC slab
c) RCC Box (cell structure)
d) RCC arches

It is generally found that when catchment area is up-to one km² a culvert is sufficient. In urban areas, for small nallahs also, culverts can do.

Pipe culverts: Pipe culverts shall conform to IS category NP3/NP4. The cushion between the top of the pipe and the road level shall not be less than 600mm. For small size structures, RCC pipe culverts with single row or more rows depending upon the discharge may be used as far as possible, as they are likely to prove less expensive than slab culverts. Diameter of pipe should be minimum 1.0m.

Alternative of providing pipe culverts by way of placing the pipe in position on concrete bed and encasing with concrete of strength of M 35 – 40 to a thickness of 400mm all-round deck laid with bituminous mix of same specification of type adjoining pavement.

Slab culverts: Slab culverts should be adopted where founding strata is of better bearing capacity or where adequate cushion is not available for locating pipe culvert. Span of slab culverts should be minimum 2m and height 1.5m.

Box culverts: Box culverts can be used where bearing capacity of soil is low.

The width of culverts should be such that the distances between the outer faces of the parapets equal the designed width of the formation of the road. Extra provision should be made for footpaths where required.

For culverts, standard sections and type plans have been prepared by the Ministry of Road Transport and Highways and published by the Indian Roads Congress. These can be utilized.

9.4.2 *Bridges*

i) The super structure of the bridge shall be designed as per IRC:112, foundation shall be designed as per IRC:78 and similarly all components of the bridge shall be designed as per relevant provisions of IRC codes and guidelines.

ii) The structural scheme, structure type, span arrangement, member size and shape for a bridge shall consider the following aspects:

   a) Operation and maintenance requirements.
   b) Functional requirements, related to the purpose of the structure.
   c) Structural requirements aimed at handling different external actions, such as gravity loads, wind, temperature, seismic, barge impact, vehicle collision, wave pressure loads, etc.
   d) Construction requirements aimed at completing the work within the stipulated time, with least disturbance to the existing traffic and surrounding environment.
   e) Environmental requirements, necessary for achieving sustainability.
   f) Durability requirements with respect to the design service life.
   g) Aesthetic requirements.
   h) Future widening requirements.
   i) Resource and energy efficiency by various possible methods (such as using less cement and more cementitious substitution with fly ash or blast furnace slag, using recycled aggregates, utilizing more industrial by products etc.).
   j) Construction technology that leads to fast track construction.
   k) Encouraging use of Integral or Continuous bridges from consideration of riding comfort and long term performance.
   l) Avoiding bridges with sharp horizontal curvature (i.e. R < 90m) and with high degree of skew (i.e. Skew angle > 30°) wherever possible.
   m) Detailing to minimize staining or discoloration.

iii) Siting of a river bridge

River Bridge should ideally be sited across the narrowest width of the river or channel where the course of the channel is straight in considerable length on both up-stream and down-stream sides of the site and the banks are stable having no history of being out-flanked. A bridge should not be sited across meandering stretches of rivers unless it is established that the banks at the bridge site are the nodal points of the river (i.e. the river has a history of touching these points year after year regardless of change in its course elsewhere). Where one of the banks is not well defined and gets over-topped, the option of training the river by construction of a guide bund can also be considered. In case the active channel of the river, especially the alluvial rivers, changes its course within the river basin, the option of training the river by construction of guide bunds on both banks can be considered after ensuring that the adjoining areas in the upstream do not get flooded or the guide bunds themselves are not under attack. The preliminary site selection can be based on information contained in the topographic sheets of the Survey of India, supplemented by actual survey or study of satellite images of the location, which can be obtained from the National Remote Sensing Agency. A model study may be required for bridging rivers having undefined cross section and huge flood plains.

When siting the bridges on up-stream/down-stream of reservoirs/dams, care should be taken about sudden release of water resulting in flash flooding submerging the bridge.

When siting close to the existing railway bridges it is desirable to consult the Railways to ascertain the HFL considered by them.

iv) Bridges in Hilly and Coastal Regions

a) For bridges in high altitude areas, where the road is likely to pass through snow bound areas and avalanche prone slopes, snow removal and avalanche control should be one of the factors to be considered in the planning and design of the bridges.

b) The bridges in coastal areas are susceptible to highly corrosive environment, storm surge, tsunami and strong cyclonic winds. These factors need to be considered in the planning and design.

v) Approaches to bridges

A length of at least 50m of approaches on either side of the bridge or the defined length up to the end of approach gradient, whichever is more, shall form part of bridge planning. The approaches of a flyover may comprise series of viaduct spans for openness in inhabited localities or wall type structures in other areas.

vi) Design life

Design life/parameters shall be adopted as per **Table 9.1**:

Table 9.1 Design Parameters

Component	Design Life
All structural components	100 years
Ancillary items like bearings, expansion joints, wearing course etc.	As per provisions of respective Codes of Practice of IRC

vii) Width of carriageway and Overall width

For high level bridges, the width of carriageway shall not be less than 7.5m for carriageway upto two-lane bridge and shall be increased by 3.5m for every additional lane of traffic for a multiple lane bridge. If a median/central verge is provided, the carriageway on each side of the median shall be at least two lanes of traffic.

Vented causeway/submersible bridges shall cater for at least two lanes of traffic.

For bridges carrying combined road and rail or any other special type of traffic, the width of bridges indicated above shall be suitably increased.

viii) Width of Median

The median width of the approach road shall generally be carried over the bridge. In case of major bridges, the median width may be reduced, subject to a minimum width of 1.2m.

ix) Width of Footpath

For bridges in urban areas, footpath shall be provided and its clear width shall not be less than 1.5m. For areas having large concentration of pedestrian traffic, the width of the footpath shall be suitably increased.

x) Clearances (Vertical and Horizontal)

a) Clearances - Navigational

Navigational clearances, both vertical and horizontal, shall be provided as per the requirements of Inland Waterways Authority of India (IWAI) or the concerned Port authorities.

b) Clearances – Over roads

- **Vertical**

  The minimum vertical clearance of any structure provided over the road shall be 5.5m.

  In case of structures over local or collector streets, where only light commercial vehicles are plying and where alternative routes for heavy commercial vehicles and fire tenders are available within a short distance, the authorities may relax the clearance requirements stated above.

  For roads carrying footways and cycle tracks, a minimum vertical clearance of 2.25m shall be provided.

- **Horizontal**

  While fixing the horizontal clearance, consideration shall be given to safe passage of vehicles on or under a bridge. The minimum clear width between any obstruction shall not be less than that of the approach roadway section, including shoulders or kerbs, gutters, and sidewalks. No object, other than a road kerb or a crash barrier, should be located closer than 600mm to the edge of carriageway.

  For a bridge constructed on a horizontal curve with superelevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by an amount equal to 5m multiplied by the super elevation. The minimum vertical clearance shall be measured from the super elevated level of the roadway. Extra horizontal clearance required for the super elevation will be over and above the increase in width required on a curve.

c) Clearances - Over railway lines

For ROBs across railway lines, horizontal and vertical clearances shall be governed by the requirements of the Railway authority.

9.4.3 *Other Design Considerations*

Choice of a particular span arrangement and the type of structure depends upon several factors such as site characteristics, type of sub-soil strata, height and length of the bridge, riding quality, design and, constructability considerations, availability of construction materials and technology etc.

i) Geometric Design

Geometric design for the bridge including immediate approach roads should essentially include integration of vertical and horizontal alignment of the bridge with the highway geometry and should broadly cover the following:

a. Preparation of Plan and Longitudinal profile – showing the horizontal alignment, horizontal curves, overall width, width of carriageway, footpath, median, crash barrier, railing, shoulders, side drains, right of way, etc.

b. Preparation of Vertical Profile – showing the vertical alignment, grade line, vertical curves, high flood level, ground/bed profile etc.

c. Preparation of Cross-sections – showing the carriageway, cross camber/ super elevation, side slopes, median, footpath, hydraulic details, structural arrangement, type of superstructure, substructure and foundation, abutment details, protection works, details of return walls, retaining walls etc.

ii) Horizontal and Vertical Alignment

a) Bridge Structure

Horizontal and vertical alignment of road bridges shall conform to relevant IRC codes (IRC:73 and IRC:86). While finalizing the horizontal and vertical alignment for the bridge portion, following aspects shall be considered:

- To the extent practicable, the alignment of roadways shall be selected to make bridge crossing as nearly straight as possible.
- Wherever the bridge is in curvature, effort shall be made to provide constant curvature within the bridge portion of the highway. Sudden change of radii and curvature over the bridge shall be avoided to the extent possible.
- Skew Angle should not exceed 30°.
- In situations where a replacement/new bridge is to be constructed, adjacent to an existing structure, width of the gap between the two bridges shall be decided on the basis of clearance between the foundations. Not less than 2.5m clear gap should be provided at any place between the two bridges to allow for working space.

- In case an additional bridge parallel to the existing bridge is proposed for widening of the additional carriage-way, the spanning arrangement of the proposed bridge needs to be same as the existing one or in multiples depending on the design.
- Locating bridges on vertical sag curves shall be avoided as far as possible, as vehicle dynamic effects are increased and appearance is adversely affected.
- For bridges, a minimum longitudinal gradient of 0.3% is desirable to provide for drainage of deck.
- In case of divided carriageways, finished road levels at the median for both the carriageways shall preferably be same at any cross section.
- The combined effect of horizontal and vertical alignments and changes in super elevation shall be considered with regard to the appearance of the bridge structure.
- The maximum longitudinal gradient on bridge shall be consistent with the gradient of the approach roads as per relevant IRC codes.
- The cross slope on bridge deck shall be consistent with the cross slope of the adjoining roadway.
- Consideration shall be given to stopping sight distance, especially where bridge approaches are constructed close to intersections.
- The super elevation and additional widening on the deck of a bridge on a horizontal curve shall be provided in accordance with the relevant IRC code.
- Transition from normal cross slope to full super elevation shall be avoided over the bridge as far as possible.
- A single vertical curve shall be provided for bridges having total length upto 30m.

b) **Bridge Approaches**

- The approaches on either side of the bridge for a length of at least 15m shall continue to have the same horizontal profile as that provided for the bridge. This length may be suitably increased where necessary to provide for the minimum sight distance for the design speed. However, in difficult geometric situations, the minimum length of approaches with same horizontal profile may not be insisted upon, provided safety concerns of users are not compromised.
- Where horizontal curves have to be provided on the approaches, beyond the straight portion on either side, the minimum radius of curvature, the super elevation and transition length for various speeds and curve radii shall be provided in accordance with stipulations contained in relevant IRC codes.
- If there is a change of gradient in the approaches, suitable vertical curves shall be introduced conforming to stipulations contained in relevant IRC codes.

- It is necessary that steps are provided in the approaches for enabling visual inspection of the bottom of the bridge.

iii) Safety Aspects

Protection to users

Railings, Parapets and Crash Barriers shall be provided along the edges of structures conforming to the requirements of the relevant IRC codes.

Protection to Structure against Vehicle Collision

Consideration shall be given for safe passage of vehicles on or under the bridge. The hazard of being hit by errant vehicles within the clear zone should be minimized by locating structural components at a safe distance from the line of users and by providing suitable protection to the structural components.

Protection to Structure against Barge Impact

For bridges on streams and rivers where barges are plying, the bridge structure shall be protected against vessel collision forces by fenders, protection islands or any other means. Otherwise, the structural system shall be designed to withstand collision force effects as specified in relevant IRC code.

iv) Hydrology and Hydraulic Design

- Data for hydraulic design shall be collected in accordance with IRC:5.
- Determination of Design Highest Flood Level.
- Design highest flood level shall be the highest of the following:
- The highest of flood levels as obtained from local enquiries from aged persons. Such local enquiries should be made at 3 different locations at site.
- It is desirable to mark HFL with year on the abutments and piers so that it will serve as reference for future.
- Level of the highest watermarks, left on different old structures or the erosion marks on the banks.
- Highest flood level that will be able to pass the design discharge as determined from other sources.
- The highest of the levels after considering the effects of confluence, backwater and HFL because of merger of or into any other river in the influence zone upstream or downstream of site.
- The highest level as corroborated from the records of HFL available for existing bridges, other structures like dams and spillways and gauge stations etc. on the river in upstream or downstream direction.
- Effect of any new structure planned for future in the influence zone of the stream.

9.4.4 *Determination of Design Discharge*

The design discharge, for which the waterway of the bridge is to be provided, shall be based on maximum flood discharge of return period of 100 years. In case the requisite information is not available, the design discharge shall be the maximum estimated discharge determined by consideration of the following:

- The discharge, waterway, scour, maximum depth of scour which depends on type of soil and afflux of the river/channel are to be determined as per methodology and procedure contained in IRC:5.
- Discharge for design of Foundation and Protection Works

To provide for an adequate margin of safety, the foundation and protection works shall be designed for a larger discharge than the design discharge given in IRC:5 and Code of Foundation and Substructure, for which reference may be made to the provisions contained in relevant IRC codes.

In case a new bridge is to be constructed close to an existing bridge for the purpose of widening or providing extra carriageway, the waterway provided in the new bridge should usually be kept the same as in the old bridge. And, if there are specific reasons for the waterway to be kept different, then it should be provided with smooth inlet and outlet transitions.

For artificial channels (irrigation, navigation and drainage), the linear waterway should be adequate to pass the full discharge at designed velocity, but concurrence shall invariably be obtained from the authority controlling the channel. If it is proposed to flume the channel at the site of the bridge, this fluming shall be subject to the consent of the same authority.

The waterway, as worked out from the formula or decided otherwise, should be compared with linear waterway at HFL corresponding to the design flood discharge and the difference in the two should be analyzed and reconciled before finally deciding the waterway to be provided.

The linear waterway as calculated above can be restricted by careful consideration of the resulting effects on flow conditions, scour, afflux and other site conditions in individual cases. No restriction in waterway should be considered for well defined and confined flow.

9.4.5 *Determination of Afflux*

If the waterway is restricted, it will cause afflux at the bridge and Design HFL will accordingly be raised.

The effect of afflux on the velocity, submergence area and scour etc shall be worked out and accounted for in the design.

9.4.6 *Freeboard*

The freeboard for the approaches to high level bridges, where water spreads along the approaches, shall not be less than the minimum values specified in relevant IRC code for road designs.

For the aggrading rivers in Himalayan foot-hills and flood-prone areas of North- Eastern States and where ever required for some specific reason, the freeboard shall be suitably increased.

9.4.7 *Vertical Clearance over HFL*

The vertical clearance shall ordinarily be provided as given under:

a) For openings of high level bridges, which have a flat soffit or soffit with a very flat curve, the minimum clearance shall be as per **Table 9.2**. The minimum clearance shall be measured from the lowest point of the deck structure inclusive of main girder in the central half of the clear opening unless otherwise specified.

Table 9.2 Vertical Clearance over HFL

Discharge in cumecs	Minimum vertical clearance in mm
Up to 0.3	150
Above 0.3 and up to 3	450
Above 3 and up to 30	600
Above 30 and up to 300	900
Above 300 and up to 3000	1200
Above 3000	1500

b) For arched openings of high level bridges having overhead decking, the clearance below the crown of the arch shall not be less than one tenth of the maximum depth of water plus one-third of the rise of the arch intrados.

c) No part of the bearings shall be at a height less than 500mm above the design highest flood level, taking afflux into account.

d) In the case of artificial channels having controlled flows and carrying no floating debris, vertical clearances less than that specified above may be provided.

e) In case of bridges in sub-mountainous region and across aggrading rivers, silting of the bed of the river should also be taken into consideration while fixing the vertical clearance.

f) In case of bridges across tidal rivers, creeks, sea, the vertical clearance shall be provided keeping in view the HTL and normal wave/splash effects.

9.4.8 *Bridge Foundation*

Bridge foundation can be open, pile or well type. The structural, hydraulic, and geotechnical aspects of foundation design shall be coordinated prior to finalization of the conceptual design and foundation type. Consideration should be given to the following:

a) Interdependence of design for foundation, substructure and superstructure.
b) Type of sub-strata.
c) Hydraulic and Hydrological considerations.
d) Constructability.
e) Effect of protection works on foundation design.
f) To prevent sand mining it is mandatory to provide protection works on either side of the bridge to restrict the accessibility by excavators.

9.4.9 *Bridge Substructure*

a) Bridge piers can be of various configurations such as wall, circular, trestle or any other shape with solid or hollow sections.

b) Bridge abutments can be of various configurations such as spill-through type and non-spill-through type with solid wall, counter-fort wall, box type or bank seat type.

9.4.10 *Bridge Superstructure*

The superstructure can be of various types. The choice of superstructure would largely depend upon the functional, aesthetic and techno-economic criteria, suited to the location of the bridge.

9.4.11 *Drainage*

The bridge deck and its immediate approaches shall be designed to provide safe and efficient conveyance of surface run-off, in a manner that causes minimum damage to the bridge and ensures safety of the passing vehicle. Transverse drainage is achieved by providing a suitable camber or super elevation, sufficient for positive drainage.

9.4.12 *Retaining Walls*

Wing walls for a bridge can be splayed type, at an angle to the bridge axis or return wall type, parallel to the bridge axis or it can be cantilever type projecting out of the abutment. Reinforced Soil walls or Gabion walls can also be provided as per the site conditions.

9.4.13 *Bearings*

a) Bearing is provided to transfer vertical and/or lateral loads from superstructure while itself undergoing rotations and/or movements. Appropriate type and arrangement of bearings shall be selected on the basis of geometry and type of superstructure, nature and magnitude of vertical and horizontal loads and direction and magnitude of rotation and translator movements. Bearing system shall be designed to ensure stability of the superstructure and desired performance of the structure as a whole. Bearings shall be designed and installed as per standards given in IRC:83 Parts I to IV dealing with different types of bearings.

b) It shall be easy for installation and inspection.

c) Bearings shall be robust and durable.

d) Provision shall be made for replacement of bearings, since the design life of bearings is less than the design life of a bridge.

e) Materials for bearings are generally elastomer, iron, steel and PTFE or their combination.

f) Bearings may not be provided for spans upto 10m. In such cases, separation layer of paper impregnated with bitumen or equivalent may be provided between superstructure and substructure.

9.4.14 *Expansion Joints*

a) The expansion joint shall be provided and designed as per relevant IRC codes and standards.

b) The expansion joints shall cater for expected movements and rotation of the structure at the joints and provide smooth riding surface.

c) It shall also be easy for inspection and maintenance.

d) Expansion joints shall be robust, durable, water-tight and replaceable.

9.4.15 *Wearing Coat*

Wearing coat over deck of bridge superstructure shall be either bituminous wearing coat or concrete wearing coat. Concrete wearing coat may be provided in case of bridges located in remote areas and in situations where accumulation of water is expected (e.g. in Underpasses). Before providing the wearing coat, it is always preferable to waterproof the deck slab of the bridge in order to provide durability to the structure.

9.4.16 *Railings, Parapets and Guide Posts*

i) General Features

Railing or parapet may be of the following type:

- Steel rolled section
- Tubular steel
- Cast-in-situ concrete
- Pre-cast concrete

The railing or parapet should be fixed and placed to correct alignment and camber throughout their length to ensure proper form, line and level.

Proper contraction/expansion gaps compatible with main supporting structure shall be provided in railing or parapet, to ensure that they function properly.

The railing or parapet should be designed for loads and forces as per relevant IRC codes.

ii) Railings for Submersible Bridges and Vented Causeway

- **Railing shall be either collapsible or removable**

  Collapsible railing shall be installed where the bridge is to be opened to traffic soon after a submerging flood has receded. Care shall be taken in the structural design of these railings to ensure that they sit well in their grooves and are not liable to displacement by floods.

  Removable type of railings may be adopted when there is no danger to the traffic using the bridge for short periods without railings. Care shall be taken in the structural design of these railings to ensure that the various members are interchangeable and can be easily removed and refitted.

  Collapsible or removable railings shall be designed to resist the same forces as specified in relevant IRC codes for railings or parapets on high level bridges.

  Guide posts/stones may be used in lieu of railings, if the submergence of the road surface over the causeway is frequent and use of removable or collapsible railings becomes unsatisfactory.

9.4.17 *River Training and Protection Works*

a) The slopes, in front of abutments and the portion of bridge approaches falling in the flood zone, shall be provided with suitably designed pitching and launching apron.

b) In case of uncertain and changing flow conditions, adequate river training works shall be provided for protection of banks, embankments and directing the river to flow under the bridge.

c) After collecting the required data, studying and analyzing the river flow conditions etc. and model studies, wherever required, the protection works shall be designed as per provisions of IRC:89 "Guidelines for Design and Construction of River Training and Control Works for Road Bridges".

9.5 Performance Requirements

The structures and their components shall be planned, designed, constructed and maintained in such a way that they perform adequately and safely during construction and service life, with following performance requirements:

a) Structural Safety and Serviceability, i.e. ability of the structure or structural members to perform, with reliability during construction and service life.

b) Durability, i.e, ability of the structure to perform during design service life, for its intended purpose with anticipated maintenance.

These requirements may be met by:

- appropriate design,
- choice of suitable materials,
- choice of span arrangement,
- construction technology
- specifying control procedures for design, production, execution, and use relevant to the particular project

9.6 Constructability Considerations

Accelerated Bridge Construction techniques shall be followed for speedier completion of bridge works. Constructability considerations aim at optimum use of required construction knowledge and experience in planning, design, procurement, and field operations, to achieve overall project objectives. Constructability drives consideration of the entire construction process during the conceptual design stage. Dimension and reinforcement of components in a bridge, many a times are dictated by the construction and erection phase requirements rather than the service stage requirements. The design therefore must consider various factors, which influence the constructability of the bridge. A typical check list of factors is given below:

— Access to work areas and remote areas/transportation of all pre-cast elements (girders).
— Access to emergency vehicles and routine maintenance of site,
— Availability of land for plant,
— Availability of materials,
— Simplicity of design and clarity in detailing,
— Ease of fabrication of steel members
— Standardization of design elements to the extent possible,
— Weather conditions and working period,
— Hindrance to existing traffic,
— Conflict with services and utilities,

- Availability of skilled manpower,
- Social and Environmental issues,
- Terrain and location e.g. mountainous, proximity to sea, desert, marine clay etc.
- Height above Water Level/Ground Level

9.7 Provision for Utilities

A bridge structure shall cater for fixtures for electric posts, lamp posts and suitable ducts for carrying electric cables etc as required to cater for utility services.

Utility services like cables and pipelines for water, gas, petroleum products directly on bridge structure should be avoided. These may be placed on a structure supported on piers and abutments.

While planning, there is need for proper accessibility of the services utilities for inspection and maintenance without hindrance to traffic movements.

9.8 Aesthetics

Bridges have large visual impacts on their surroundings. To achieve aesthetically pleasing view of bridge and its surroundings, it is essential that attention should be paid to produce a clear, simple, well-proportioned structure form, blending harmoniously with its surroundings. Larger the length of a bridge, greater is its visual impact.

Bridges should complement their surroundings, be graceful in form and present an appearance of adequate strength. Bridge designers must therefore consider appearance as an important design consideration. Attention should be given to appearance while looking towards the bridge as well as that while moving on the bridge.

The visual appeal of the bridge can be attributed to its form, texture, colors and other details. Every visible component of a bridge has a role to play. Aesthetics of a bridge must be considered both in the conceptual planning stage as well as in the detailed design stage. Therefore, specialists in architecture and landscaping may be engaged for bridges exceeding length of 300m for providing their inputs on aesthetics.

9.9 Operation and Maintenance

A structure will properly serve its intended design life only when it is regularly inspected and maintained in accordance with the IRC codes and guidelines. For inspection, guidance may be taken from IRC:SP:35 "Guidelines for Inspection and Maintenance of Bridges".

Proper attention shall be given to ensure all critical components of the structure can be properly accessed and inspected. Therefore, proper access/arrangement for inspection of bearings, anchors, interior of box girders and the like, should be thought of at design stage. Bearing replacement scheme, where applicable, shall be planned at design stage and corresponding forces should be considered while designing various components of the Bridge.

Exposed parts of steel structures shall be accessible for inspection and periodic painting. Design documentation shall include indicative procedures for replacement as well as repair of bridge components, like bearings, corroded anchors, expansion joints, drainage spouts, vegetation at joints.

A maintenance manual shall be prepared for the bridge project. Proper and adequate maintenance also helps in improved safety for road users.

There is need for the urban road authorities to institute a Bridge Management System as part of asset management system for all urban roads infrastructure.

CHAPTER 10

GRADE SEPARATORS, ELEVATED ROADS AND ROAD OVER/UNDER BRIDGES

10.1 Introduction

This Chapter covers relevant aspects and practices required to be considered in the Planning, Design, Construction and Maintenance of Grade Separators, Elevated corridors, ROBs and RUBs. The requirements and provisions may be followed as per relevant IRC Papers and Manuals.

10.2 Type of Facility

The structures (grade separators, elevated roads,subways) are proposed essentially to segregate traffic in space and depending upon prevailing and expected traffic flow present and proposed development plans for the area, site constraints and environmental considerations, could take relevant forms. The type of these facilities to be provided at any particular junction or crossing will depend on the following main factors:

a. Location attributes- whether in open areas or urban areas
b. Traffic flow and level of service requirements
c. Future development plans
d. Road classification and function
e. Local constraints – ROW, utilities and services, important structures
f. Design and construction requirements
g. Distance from the nearest existing or proposed grade separator

The hierarchy of the road, volume of traffic carried and site condition will decide the one that would remain at level and the other that would be elevated. It is desirable to keep the higher traffic road to remain at level instead of roller-coaster unless there are some specific considerations or constraints.

Road Over Bridges (ROBs) and Road Under Bridges (RUBs) are being provided in replacement of existing Railway Crossings on the road network both in rural areas and urban areas. The ROBs/ RUBs are grade separated structures and their Design and General Arrangement Drawings need to get approval of the Railways.

10.3 Planning and Design of Grade Separators and Elevated Roads

Grade Separators in open areas, are not confronted with the same degree of site constraints as in town/urban areas. Grade Separators/elevated structures in open areas tend to take more liberal forms than those in urban areas. However, planning of grade separators, elevated roads and subways in urban areas is (**Photos 10.1** and **10.2**) guided by constraints of space and of underground or overhead services, environmental considerations, aesthetics and urban design norms. The Authority has to keep in view the city and its corridor layout pattern.

Photo 10.1 Grade Separated Elevated Roads in Urban Area

Intersections are usually closely spaced in a city and while planning a Grade Separator at an intersection, the impact of the facility on the adjoining intersections must also be assessed. While hierarchical pattern of road network remains an important factor in planning urban Grade Separators, the traffic characteristics at the intersection remain the decisive factor to this effect. Traffic studies thus become a key activity in this context. It is desirable to space grade separators at least one km apart in Central Business District (CBD area) and two to three km on ring roads. The traffic movement from intersections in-between can be stream lined as suggested in drawing. (**Fig. 10.1**)

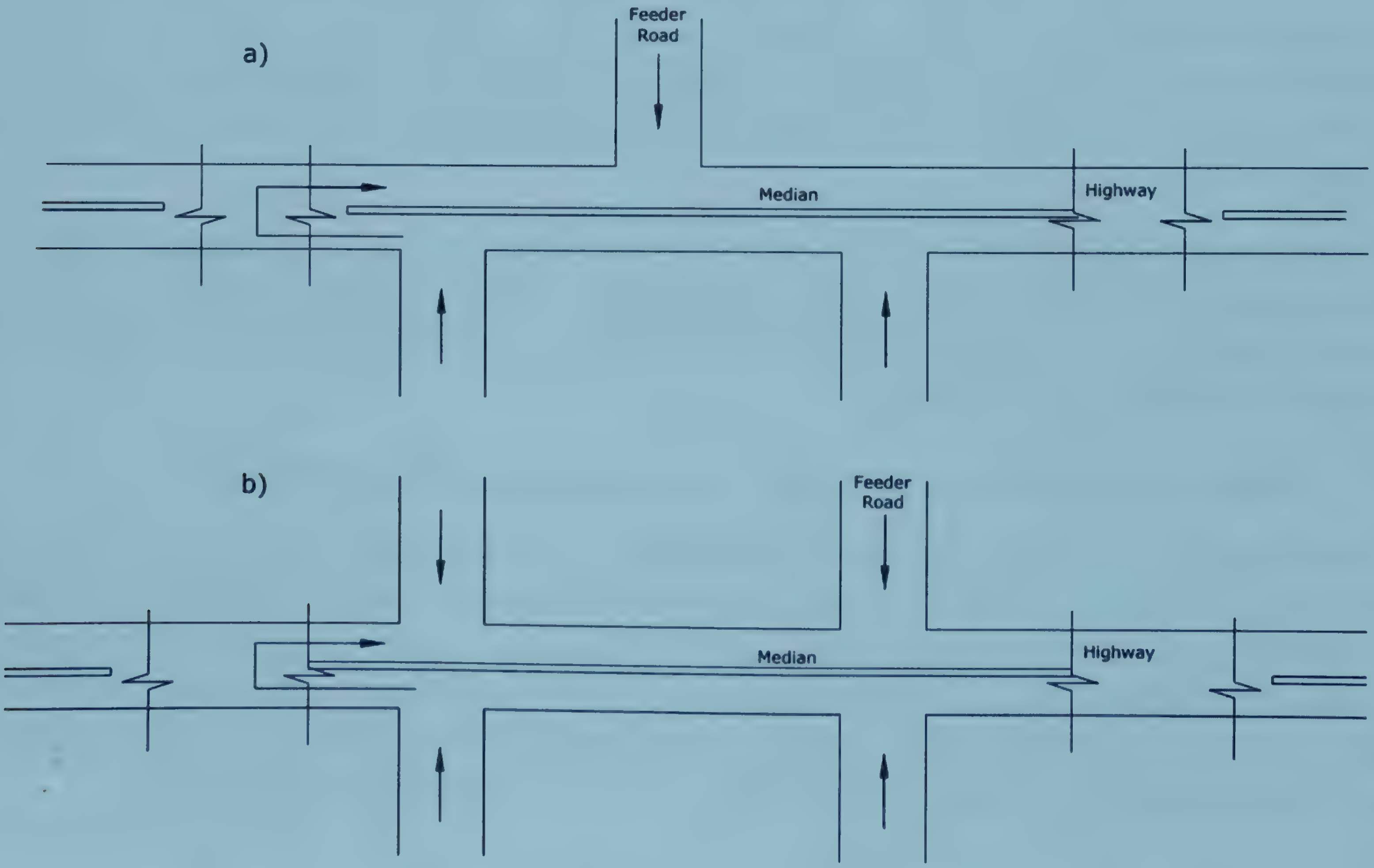


Fig. 10.1 Traffic Movement at Intersection

10.4 Traffic Analysis

Traffic facilities in urban areas are usually planned for catering to peak hour traffic demands. It is thus necessary to identify the peak hour and the peak hour traffic characteristics at such urban intersections. In case, Average Annual Daily Traffic (AADT) calculated over 365 days a year is available for the base year such data would also be made use of in the planning process. The ADT or the AADT must however, be available with an hourly split up of traffic volumes. For an existing intersection, data on intersection delays must be collected. This information becomes necessary for establishing the viability of the scheme. Design traffic volume could be defined as that hourly volume of traffic by the design year for which the facility is to be planned. Usually, such a facility has a design life of 20 years after construction and as such, design traffic volume will refer to the design hourly traffic volume at the end of the design life. Determination of design hourly volume requires assessment of peak hourly traffic during the base year and projecting the same to the design year.

Other information to be collected would include information on bus routes and locations of bus stops, hourly volumes of pedestrians crossing the intersection approach arms overhead and underground services and development plans, if any, for the adjacent quadrants.

With the increase in traffic volume particularly in large cities the flyover/subways may not give a good perfect solution and it is desirable to elevated corridors possible connecting intercity highways through the cities that are not having bypass. As a fast corridor and even if a few junctions of this corridor do not qualify for elevated structures based on capacity analysis, in such a situation, consideration may be given to continue elevated roads over these intersections also.

10.5 Alignment and Layout

The alignment and layout need to avoid passing or covering congested areas or locations with under-ground utilities/services or where meeting out the requirements of the geometric design standards are not feasible.

10.6 Geometric Configuration

The type of elevated structures, grade separators and ROBs is influenced by many factors, such as urban road classification, character and composition of traffic, design speed and degree of access control. These controls plus design requirements, economics, terrain and right-of-way are important in designing these facilities with adequate capacity to safely and efficiently accommodate the traffic demand.

Simple grade separators are provided when the high volume traffic is to be segregated by the elevated structure. The rest of the traffic still passes at level roads. Thus the traffic is to be segregated from one another and all traffic is to be made signal free. The ability to accommodate high volumes of traffic safely and efficiently through intersections depends largely on what arrangement is provided for handling intersecting traffic. The greatest efficiency, safety and capacity are attained when the intersecting through traffic lanes are separated in grades. An interchange is another system of interconnecting roadways in conjunction with one or more roadways or highways on different levels. For this, refer to Chapter 4 “Intersections and Interchanges”.

10.7 Land Requirement

i. Planning of grade separators and elevated structures in urban areas requires special consideration for fitting them within the constraints of the urban scenario. Very often Right-Of- Way (ROW) is restricted in a developed urban situation; both in the horizontal and vertical direction on both sides of ROW leading to curves with reduced radii.

ii. Alternative of taking each carriageway of grade separator along two different alignments may be considered to minimize the acquisition of land. The vertical profiles are constrained due to the presence of traffic junctions very closely spaced to one another leading to gradients steeper than those permitted by prevalent design codes.

iii. In such situations, especially in urban areas with sanctioned development plans, specific conditions may be required for the relevant geometric parameters and are summarized as being "Desirable", "Normal" and "Acceptable"

    a. Desirable- which in the normal course must be executed on any part of the structures.

    b. Normal- which is less than desirable parameter and which can be used in case it is not possible to achieve desirable parameter.

    c. Acceptable which can be used in exceptional circumstances for which competent authority's approval may be sought.

The alternative of extending the deck of the flyover/elevated road within the said pack of the structures can also be considered in consultation with the Urban Authorities.

Geometric standards may be fixed as per the recommendations in IRC:86 "Geometric Design Standards for Urban Roads".

10.8 Relocation of Utility Services and Removal of Trees

The study and mapping of all the overhead and underground utility services, OFC, electrical, telephone cables, water supply and sewerage pipes, gas pipes or structures, encroachments falling in the project area is important step in the planning, design, construction and maintenance of grade separators and elevated roads.

All data has to be collected from the records of the concerned organizations or utility agencies and by surveying and investigations at site. Coordination of all the concerned is required for timely completion of the project. Acquisition of land is primary consideration for relocation of utilities. Subsequently programming and cost estimate for relocation of utility services, shifting or relocation of utility services, structures and removal of encroachments and removal of trees. A detailed plan of these existing services and structures should be made and then plan prepared for removal, shifting or relocation concerning all the departments separately in consultation with them. If any augmenting of services is required the same may be planned and executed under the present project itself.

10.9 Acquisition of Land and Structures

Many times it may not be possible to plan an elevated structure facility within the land available in ROW limits of the concerned department. As such, assessment of land to be acquired and estimation of costs has to be made as per the final layout of the grade separators/elevated structures. The acquisition of land may also include the land required temporarily for diversion roads, if any.

The detailed plan of acquisition of the land and the structures has to be made and cost of acquisition worked out to be part of the project cost. The necessary procedure to acquire the land should be initiated well in advance so that the project is not delayed on this account. Procurement of works should not be undretaken till such time required land is in possession of the executing agency and also shifting of utilities is completed.

10.10 Services allowed to be carried on the Elevated Superstructures

Wherever required, the elevated structure shall cater for traction wire supports, poles or pillars for lights, trenches or other suitable ducts for electric supply. Such structures are normally not expected to carry other utilities. However, in urban areas and particularly those involving crossing of railway lines (ROBs), other services and utilities such as telephone/power lines, water mains and gas line may need to be carried on the bridge structure. While planning, attention should be paid to their arrangement, location, accessibility and prevention of structural damage to the structure. It is recommended that water or gas mains should be supported on brackets projecting from the main structure whereby damage, if any, is limited to the bracket and does not spread to the bridge structure. It is necessary to provide access to relevant utilities which are required to be maintained frequently.

10.11 General Features and Geometric Standards

The objective of geometric design is to provide maximum efficiency and safety in traffic operations. General features and geometric standards shall be based on IRC Codes.

Carriageway Width

The carriageway width shall be provided as per IRC Codes for the traffic requirements as determined by traffic studies. The carriageway width on the elevated structure shall be kept same as on the approaching roads on either side and the widths shall not be reduced abruptly. The carriageway width on the connecting one way loops or curved structures shall not be less than 2- lanes. Extra width shall be provided on curves as per the relevant IRC Codes. Suitable merging and diverging lanes shall be provided. **Table 10.1** gives key requirements.

Table 10.1 Geometric Design Standards: Key Requirements

Sl. No.	Design Parameters	Reference Code/Design Values
1	Design Speed	IRC:69 – "Space Standards for Roads in Urban Areas" IRC:86 – "Geometric Design Standards for Urban Roads in Plains" IRC:92 –"Guidelines for the Design of Interchanges in Urban Areas"
2	Carriageway	Three lane carriageway with raised kerbs – 11.0m Two lane carriageway with raised kerbs – 7.5m
3	Median	1.20m

Sl. No.	Design Parameters	Reference Code/Design Values
4	Footpath	As per site requirements, Minimum of 2.0 meter as either side check
5	Camber (bi-directional)	2.5 % for paved carriageway
6	Super Elevation	Limited to 4 percent
7	Horizontal Curves	IRC:38 – "Guidelines for Design of Horizontal Curves for Highways and Design Tables" (First Revision).
8	Vertical Curves	IRC:SP:23 – "Vertical Curves for Highways"
9	Gradient (Permissible)	Entry (up) Ramps – 4.0 % (1 in 25) Exit (down) Ramps – 5.0 % (1 in 20) Extra width at the up and down ramps would be desirable to prevent traffic hold up on the grade separator Minimum Gradient for Drainage – 0.5 % (lined) & 1% (unlined)
10	Clearances	Vertical clearances under flyover – 5.5m Minimum lateral clearance of flyover structure from building line – 1.0 m Clearances (both horizontal and vertical) in respect of Railway Over Bridges shall be governed by the requirements of the Railway Authority.
11	At-grade Junction	IRC:SP:41 "Guidelines on Design of At Grade Intersections in Rural & Urban Areas"

10.12 Construction Methodology and Structural Forms

Construction Methodology

The substructure can be open foundation in case of hard strata at shallow depth or pile foundation this requires thorough study of geological information and trial bore.

Depending upon the length of span, space available, ease and speed of construction required, other restraints of traffic movement and regulations, limitation of movement of machinery and material and environmental issues and requirements, one of the following methods may be adopted for construction of superstructure:

a) Cast-in-Situ on staging
b) Pre-cast at site or in casting yard and then erected or launched
c) Segmental-Cast-in-situ or pre-cast
d) Composite construction with structural steel
e) Push in or incremental launching

Either girders of one span length or short segments of full deck width constitute the basic element of construction for the superstructure.

Methods of Construction

Besides usual methods of casting on staging, erecting or launching, the segmental construction is more often used to facilitate smooth flow of traffic during construction especially in urban situations and for increased speed of construction. Guidelines for segmental construction in IRC:SP:65 may be referred to.

Structural Forms

The structural forms for the superstructure can be chosen from the following for arriving at the most befitting, convenient and economical solution or any other forms suiting the conditions at the site:

- Solid slabs - RCC or Pre-stressed
- RCC Beam-slab arrangement, where the view from underside or elevation is not very important.
- Box type superstructure
- Closely touching beams
- Voided slab
- Composite, Pre-cast Pre-stressed concrete beam or steel girders with RCC cast-in-situ deck slab construction Pre-cast, Pre-stressed girders made continuous by using cast-in-situ cross diaphragm.
- Integral structure such as rigid frame units
- Extra dosed structures
- Cable stayed structures

Structural form of superstructure should be so chosen, wherever possible, that its depth is minimum which will reduce the length of the grade separators.

The superstructure should, as far as possible, consist of continuous spans, instead of simply supported ones. This helps in reducing its depth, improving the riding quality and durability and also improves its aesthetic appearance.

RCC Slab up to 10-15m span and Pre-stressed slab upto 20m span range can be used. Span range and economics of solid slabs can be enhanced by choosing continuous spans and increasing their depths at supports by a profiled soffit.

RCC Beam and Slab arrangement can be used up to 20-25m spans. For larger spans, Pre-stressed concrete girders or steel plate girders with RCC slab can be used up to 35-40m. Continuous RCC voided slab can be provided upto 20-25m. For 25 to 35m span, pre-stressed voided slabs may be used, wherever feasible and economical.

Simple Box girders are quite efficient forms up to 60m as simply supported or continuous construction, but also have a wide range of application for longer spans and particularly when segmental construction is used. Box girders, in general, should not be used indiscriminately in Grade Separators structures, as they can look bulky and disproportionate for short spans.

Integral type structures are useful for medium or small span ranges. These are maintenance free and give better riding quality as bearings and expansion joints are not required.

An extra dosed bridge is more suited to longer spans ie. 50-150m than a conventional girder bridge and be a good alternative where the site considerations require longer span without causing any obstruction to traffic.

Use of cable stayed deck instead of simple box girder will result in reduced thickness of deck. This may be better solution than adopting simple box girder for the obligatory spans of grade separators, usually about 40-60m, because the greater depth of box girder than those of other spans increases the formation level resulting in longer Grade Separators, increased height of embankment and consequently increased cost.

The cable stayed structures are usually not feasible or economical for the grade separators/ elevated girders, sometimes can be preferred to give a better and efficient construction methodology. Two-spans with single pylon cable-stayed, may sometimes be constructed alongside the expressway, then rotated about the pylon into its final position spanning the freeway without closing the road traffic. The second span which will act as a counter weight, may be buried under fill to make it completely invisible in the finished structure.

10.13 Substructures

The type of substructure that can be adopted will have constraints arising out of width of the grade separators, foundation problems arising out of location of underground services, if any, requirements of openness. The geometrical shape (along width of grade separators) of the pier should be suitable to enable its adaptation to variable heights (where the height of piers is varying as in the approach portion). Vertical shape or some other geometric shape where proportions look pleasing to the eye in spite of change in one dimension (i.e. height) may be adopted.

Single circular or oval piers may be suitable where least construction space is to be occupied. They look lighter and less massive. Since it is a land structure, stream line shapes are not required.

Piers can be shaped and treated in many attractive ways. The vertical grooves can be introduced to accentuate the height and break the impact of width and horizontal grooves to emphasize the mass of piers and to attract attention. The mass of the abutment can be used to form sculptural treatment.

Elimination of pier caps by providing bearings directly over columns or piers is also useful in achieving the lightness and smooth transition between the substructure and superstructure. Continuous wall type piers are usually not required in case of grade separators and can be avoided as visual transparency of the substructure is more important at these locations for better visibility of traffic and the requirements of aesthetics.

Row of columns may be avoided at the pier locations from aesthetic consideration. Where feasible from the design considerations and where only a few large diameter piles in one row have been used as foundations, the piles can be extended above the ground up to pier cap level to eliminate heavy pile caps. The abutments for the viaducts can be separated from the earth fill by providing a gap topped by a slab and earth being retained by reinforced earth wall. The load bearing abutment can then be designed without earth pressure and heavy sections may not be required.

The suitability of a particular type of foundation is decided on the basis of availability and depth of suitable bearing strata, feasibility of excavation, boring or sinking efforts required for the foundations, settlement criterion and space constraints, obstructing utility services or adjoining rail lines and properties.

Selection of proper type of foundation is crucial as it governs the cost and time of completion of the project. Sufficient study, analysis and cost comparison should be done to decide this parameter where alternative types are feasible so that both economy and speed are achieved. It is desirable to use same type of foundations for a given structure to avoid dissimilar settlements which would lead to inconvenient profile of road, poor riding quality and damage to the expansion joints.

In many cities, the existing service lines create obstructions for the ideal location of a foundation. In such cases, it becomes necessary to devise special solutions which include use of eccentrically loaded foundations or odd shapes or separate foundations or portal frames. This kind of foundation across service line is also achieved by use of piling, where possible. The costing of relocating the utility and cost of foundation may be cost of alternative may be worth out and least cost can be adopted. While adopting a particular type of foundation, it should be ensured that it will not create any problem during construction to the traffic or the adjoining areas.

For casting of piles, sufficient horizontal and vertical space should be available for moving the rig, for installing and erecting the rig and for operation of boring at every foundation location. Enough space should also be available for testing of piles for making platforms and for loading. It should be explored whether driving or boring of pile will cause any adverse effect on adjoining area, structures or services. Short piles should be avoided as far as possible.

10.14 Design Parameters

All parameters specific to grade separators construction be explicitly followed as per IRC Codes. This should include gradient, super elevation, curves, median dividers, others.

The different structural alternatives for grade separators need to be considered looking into the advantages and disadvantages of each type.

A section on split grade separators, undivided grade separators, median divided grade separators needs to be considered while designing for motorcycle safety. Items that need to be covered should include horizontal curvature, S-curves, side barricading and walls, kerb area, others.

The minimum length required for grade separators of different types, and the minimum distance of the foot of the Grade Separators to the next junction be considered.

10.15 Materials for Construction and Specifications

The material for the grade separators is generally concrete. But steel is also a good option, many times, for superstructures and sometimes for pier and abutments also. Composite Steel construction is also in practice at suitable locations.

One of the considerations in selecting the type of material is that construction should be possible without causing too much inconvenience to the existing traffic for a long time. Use of High Grade or High Performance Concrete can be made to make the structure look slim and more durable. Use of anti-corrosive steel or steel with anti-corrosive coating can be made in marine or corrosive environmental conditions. All the materials selected for construction will conform to relevant IS Codes.

10.16 Loads

Loading standards shall be in accordance with IRC:6 except for the loads and part or full clauses, which are exclusively applicable to river bridges.

10.17 Minimum Dimensions

The minimum dimensions of the components shall follow the provisions of IRC Codes. To permit inspections of the inside of the box girder, the minimum overall depth of the section may be kept to about 2.25m, if feasible.

10.18 Design for Continuity

The continuity of the superstructure may be achieved by providing full continuity or continuity for live load only. This is achieved by providing superstructure longitudinally continuous over intermediate supports on bearings.

In case of Pre-cast girders, this is achieved by casting in-situ slab and diaphragm on them after placing them in position. The superstructure can be made continuous through deck slab also by two types of arrangements, one by continuous separated deck slab in which the deck slab is continued monolithically over the intermediate piers without continuing the girders. The other is tied deck continuity in which the deck slab is hinged over the pier using partly debonded dowelling.

The design of Continuous girder be done using the guidelines given in IRC:SP:66. Rigid frames are designed for settlement of 10mm. In case of such structures, the width to span ratio is quite small, the effect of these wider decks on the dispersion of the loads should be duly considered and adequate provisions made to ensure the structural response as per the design.

10.19 Approaches

The approaches on either end (excluding culvert) of any straight stilted portion shall have minimum straight length of 30m, except where a single vertical summit curve has been provided, having a minimum surfaced width equal to the roadway on the grade separator itself. This may be increased, where necessary, to provide minimum sight distance for the design speed.

Where horizontal curves have to be provided on the approaches beyond the straight portion on either side, the minimum radius of curvature, the super-elevation and transition length for relevant speeds and curve radii shall be in accordance with relevant IRC Standards.

If there is a change of gradient, suitable vertical curves shall be introduced conforming to IRC:SP:23.

10.20 Approaches in Urban Locations

In urban areas sufficient width is not available and wider roads and drains are required on all sides. Earthen banks also require considerable quantity of earth which has to be brought from long distance. Considerable costly land is occupied by the approaches. Solid earthen embankments also obstruct the view and do not look good. As such earthen approaches are usually not considered in such locations. Viaduct spans up to a height of 3m can be provided so that in the last span a vertical clearance of 3m is available. This may be followed by the earthen embankments or retained embankment either by retaining walls or reinforced earth walls.

10.21 Utilization of Space below

Provide landscaping and plantations so that surroundings look clean and aesthetically pleasing. The space below is not to be used for parking.

10.22 Retaining Walls and Return Walls

The retaining walls should be usually simple cantilever type with correction in front slope for the deflection. Counter fort retaining walls should be provided only where specifically required and economical. Splayed return walls should be avoided in urban situations.

10.23 Reinforced Soil Structures

The reinforced soil walls can be designed as per the provisions of IRC:SP:102 "Guidelines for Design and Construction of Reinforced Soil Walls". Reinforced earth retaining walls constructed with soil backfill reinforced with inextensible flexible reinforcement, such as metallic strips or sheets or extensible geo-synthetic materials, such as; geo-textiles and geo-grid, are used for solid ramp portion for approaches of grade separators, elevated structures and or embankment. It does not cover load bearing abutments.

Selected fill and filler material conforming to specifications given in relevant IRC standards are used in the reinforced soil structure as back fill behind fascia panels. The material is granular and purely non-cohesive. It should be properly compacted in the designed thickness of layers as specified. Geo-synthetic material may be woven, non-woven or knitted sheet used in geo-technical engineering and other civil engineering applications that sustain design loads at permissible strains and defined creep characteristic with maximum elongation less than the permissible limit as detailed in IRC:SP:102.

Metallic reinforcement is in the form of strip or rod or square welded mesh/net which sustains load at strains less than or equal to the value permitted in the code. The facia panels should be cast with proper line, finish and locking pattern to provide holding of individual panels preferably in a casting yard. They can be given different treatment with patterns to suit the aesthetical requirements or giving any effect.

The fascia panels should be erected to give uniform surfaces and fixed to the reinforcing materials such that these are not dislodged. The drainage layer of prescribed specifications should be provided as required by design and specifications and it should be ensured that it will remain functional and will not be choked because of flow of silt particles in the backfill, during the outflow of water, as it may result in the failure of embankment.

10.24 Inspection and Maintenance

The joints and openings in the panels in the grade separators, elevated structures and ROBs in urban areas are the locations where growth of vegetation is seen proper care and timely removal and chemical treatment to discourage further growth need to part of maintenance the flyovers need to be kept traffic worthy. It is necessary that all elements are regularly inspected during and post construction as per predetermined program and for specific maintenance repair or rehabilitation. Provisions of IRC:SP:35 may be followed except its clauses which are for river bridges only.

A well drawn out maintenance methodology is required to be uploaded and also hard copy readily available with the concerned.

10.25 Access for Inspection

To facilitate inspection, suitable facilities should exist for the personnel to access the parts or activities which are to be inspected during construction or after construction or for maintenance. Mobile inspection units can be deployed wherever feasible, or local arrangements suiting the requirements of inspections can be made.

For Elevated Corridors, access vestibule at one end may be ideally suitable. Such a vestibule provides easy access to the inside of the box girder and even heavy equipment can be taken through this vestibule. This area can be used for housing bridge monitoring equipment. This also helps in relieving the earth pressure surcharge on abutment. Expansion joints provided at the end of girders on the top of pier and abutment need regular inspection. A suitable space between the end faces of main beams or an inspection gallery around pier facilitates this inspection.

Leakages from the drainage spouts or down take pipes should be noticed and remedial measures taken immediately. Inspection of drainage spouts can be done from footpaths.

Deflection/Camber monitoring is an important aspect of inspection. Suitable platforms constructed to facilitate taking readings will be helpful in monitoring deflection/camber of the girders. Some 100mm square patches made even at regular longitudinal and transverse intervals (as reference locations on the carriageway) could be used for periodic collection of profile data. Such periodic deflection/profile monitoring of the superstructure enables taking appropriate corrective measures including resurfacing. Where footpaths have not been provided, a walkway or gangway is helpful for inspection and maintenance personnel.

10.26 Road Subway

Road subway can be considered as an alternative for flyover based on site condition including drainage. (**Photo 10.2**)

Photo 10.2 Road Subway

10.27 Road Over and Under Bridge

The existing rail level crossing need to thoroughly examined and the level of intersecting and surrounding roads and rail level to arrive at weather ROB or RUB would be suitable and the cost consideration. Such proposal need to be examined by the local body and then finalized in consultation with the Railways. If sufficient clearance is available box pushing can be considered than adopting ROB. The other standards are to be in accordance with the IRC standards. An alternate of reduced vertical clearance could be considered depending on the movement of traffic and possibility of alternative roads. (**Photo 10.3**) All railway crossing on roads in urban areas should be replaced with road over bridge or road under bridge. Designs should be finalized in consultation with the Railways.

Photo 10.3 Road Under Bridge

CHAPER 11

URBAN TUNNELS

11.1 Background

This chapter draws heavily from the IRC document on "Guidelines for Road Tunnels" IRC:SP:91. The tunnel option for urban roads is usually adopted with a view to traverse a physical barrier such as a mountain/hill range or water body, or areas subject to landslides, or for environmental reasons (noise pollution). Tunnel options have also been increasingly adopted in recent times in urban settings as grade separation structures.

11.2 Classification

Tunnels are classified into various categories as given below:

i) Based on Location: Underground tunnels from environmental or other considerations, or carried under water bodies or hill in urban areas.

ii) Interchanges and grade separation tunnels: Separation structures where road is taken underground for movement of vehicles or pedestrians

iii) Based on shapes: Tunnels are also classified based on shapes e.g. D Shaped, Circular, Horse Shoe or Egg Shaped, etc.

iv) Based on construction method: Tunnels could be classified based on the method of construction e.g. Drill and Blast Tunnels or No Blast Excavation tunnels.

v) Based on Length: Short tunnels upto 500m long, medium tunnels with length between 500m and 1500m and long tunnels more than 1500m long.

11.3 Distinctive Features

Distinctive features of tunneling are as under:

i) Space inside tunnel is limited and therefore calls for use of specially designed plant and equipment.

ii) Due to space limitations and linear nature of work, not many operations can be carried out simultaneously particularly at the tunnel face. Delay caused at any stage gets carried through and rarely made up.

iii) Conventional methods of tunneling are normally with cyclic drilling and blasting.

iv) Adequate ventilation and lighting need to be provided during construction.

v) Even in the compact and hard rock, possibility of meeting jointed and weak zones leading to accidental rock falls cannot be ruled out. A tunnel can pass through complex geological formation where adverse geological occurrences like rock blasting, squeezing, swelling, sudden ingress of water, emission of inflammable, poisonous and noxious gases and highly geothermic zones could be encountered.

vi) Urban tunnels could pass below populated areas and built-in structures where surface subsidence and ground vibrations are of paramount consideration.

vii) Planning and design of tunnels calls for a good understanding and appreciation of the geological aspects.

viii) Tunneling being a hazardous operation, appropriate Safety, Health and Environmental measures must be implemented.

11.4 Planning

Road tunnels in urban areas are essentially roads taken inside tunnels or grade separation structures. Surveys, investigations and project preparation for such roads would obviously *inter alia* include the following activities:

i) **Collection of Data:** With respect to volume, intensity and type of traffic, loadings, climatic conditions and geotechnical investigations, space restraints and limitations because of underground and overhead utilities services and existing geometrics. Traffic studies should include Classified Traffic Volume Survey, Turning Movement Count Survey, Vehicle Occupancy Survey, Roadside Origin-Destination Survey, Vehicle Speed and Delay Survey, Intersection Volume Delay Survey (for grade separation tunnels). All these data should be collected. Studies, investigations and analysis should be carried out for deciding the various parameters such as shape, size, type and configuration.

ii) **Coordination with various authorities:** e.g. urban local bodies, traffic police, various utilities departments etc.

iii) **Preparation of Index map showing the location**

iv) **Conceptual Plan:** The evolution of the concept plan would involve the type and classification of the tunnel facilities to be provided and will mainly depend on factors such as Location Attributes- whether in open areas or populated urban areas, analysis of traffic studies and data collected, future development plans, roadway classification, capacity and level of service required – ROW, underground and above ground utilities and services and environmental issues as well as design and construction requirements. The design and construction requirements take into account the horizontal and vertical alignment and geometric elements of tunnel e.g. shape, length and width of the tunnel. One of the major considerations would be the decision about whether a bi-directional or uni-directional tunnel is proposed to be provided. For ease of reference, the following important provisions of IRC:SP:91 are brought out here:

   a) **Cross section:** This depends upon projected traffic volume, provision of ventilation system (if any), geology of the area and provision for pedestrian movement which is an important consideration in an urban scenario. The cross section of the tunnel would incorporate the number of lanes to accommodate the future projected traffic, emergency lanes, footpaths/walkways, crash barriers, kerbs, railings and drains.

   b) **Width:** While the lane width of highway tunnel should be 3.5m, in urban areas, width may be reduced to 3.2m and even to 3m for low traffic roads. As far as possible, the width of carriageway in the tunnel should be the same as that of adjoining carriageways in open air. If the width of traffic lane in the tunnel is restricted as compared to the width of the traffic lane on the adjoining carriageway in open air, such restriction shall commence at least 150m ahead of the entrance of the tunnel along with speed restriction.

c) **Height:** The finished height of the tunnel shall depend upon the minimum vertical clearance which shall not be less than 5.5m. While the minimum vertical clearance can be reduced for low traffic volume roads, the same shall be as per the local regulations and to allow passage of loaded vehicles likely to pass through such tunnels. Such minimum vertical clearance shall be available for the full width of the carriageway.

d) **Bi-directional Tunnels:** For tunnels on low traffic volume roads, bi-directional two lane cross section shall be adopted. For roads with projected daily traffic of more than 10000 PCUs, twin tunnels each of two or three lanes may be adopted as per requirement. The twin tubes shall be separated by a distance of at least 0.5 to 0.2 times the width of the tunnel depending upon the strata, stresses generated and their effect on stability.

e) **Typical sketches:** Typical sketches indicating tunnel cross- sections for bi-directional and unidirectional traffic conditions are given hereunder. See **Figs. 11.1** to **11.5**.

Table 11.1 Legend for Symbols Used in Sketches

Symbol	Particulars	Unit	Dimensions
A	Traffic Lane Width	mm	As per design
B	Pavement Thickness	mm	Type and Thickness as per design requirements
C	Pavement Camber	%	Around 2 percent
D	Edge Strip Width	mm	Minimum 500 for Running Tunnels and 1000 for Cross Passages
E	Crash Barrier Width	mm	Type and Dimensions as indicated or as per design
F	Kerb Width	mm	Minimum 500 thick and 1000 high
G	Drain Waterway Width	mm	As per design and enough to accommodate the Footpath/ Walkway above.
H	Drain Wall Thickness	mm	As per design
I	Drain Floor Thickness	mm	As per design
J	Drain Waterway Depth	mm	As per design
K	Footpath/Walkway Slab Thickness	mm	As per design
L	Railing height	mm	As per design
M	Width of Median	mm	As per design
R	Radius of Roof arch	mm	As per design

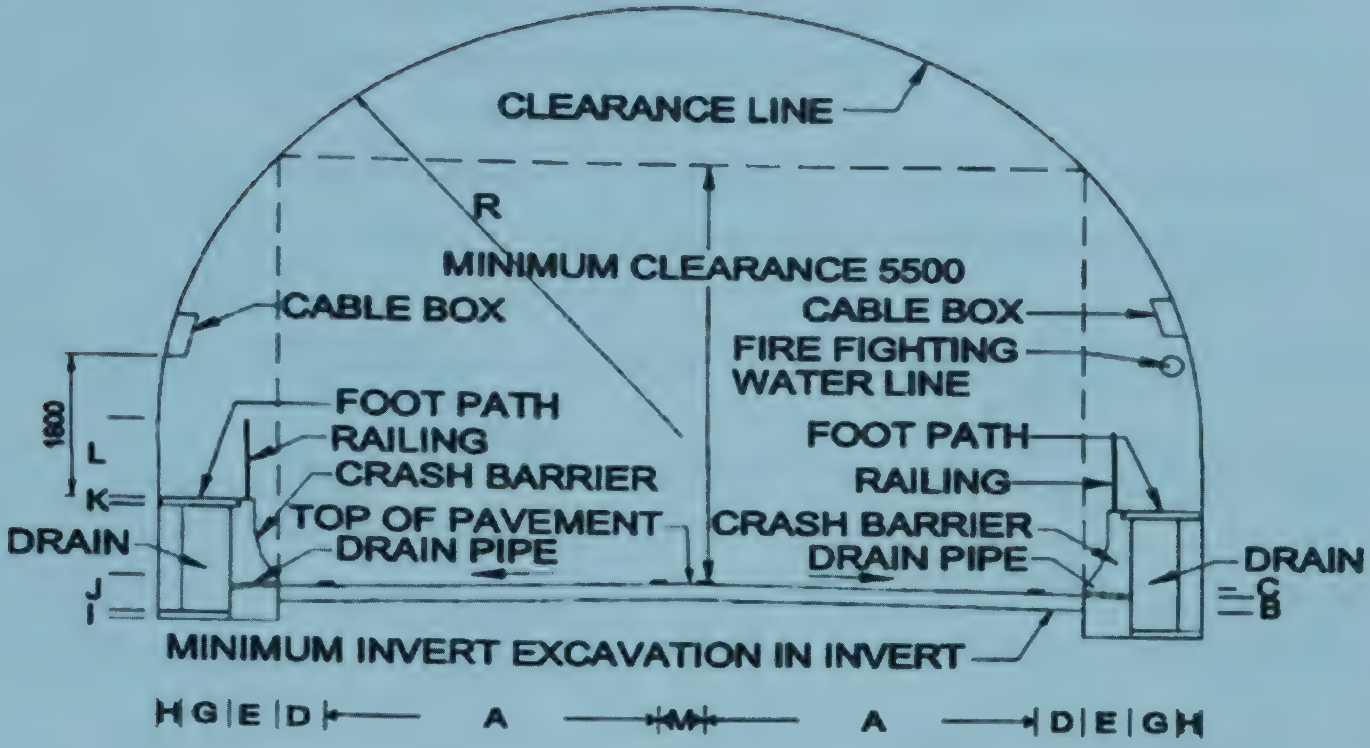

CLEARANCE LINE
R
MINIMUM CLEARANCE 5500
CABLE BOX
CABLE BOX
FIRE FIGHTING WATER LINE
1800
L
K
FOOT PATH
RAILING
CRASH BARRIER
TOP OF PAVEMENT
DRAIN PIPE
DRAIN
J
I
FOOT PATH
RAILING
CRASH BARRIER
DRAIN PIPE
DRAIN
C
B
MINIMUM INVERT EXCAVATION IN INVERT
H G E D A M A D E G H

Fig. 11.1 Section of Two Lane Bi-Directional Traffic Tunnel

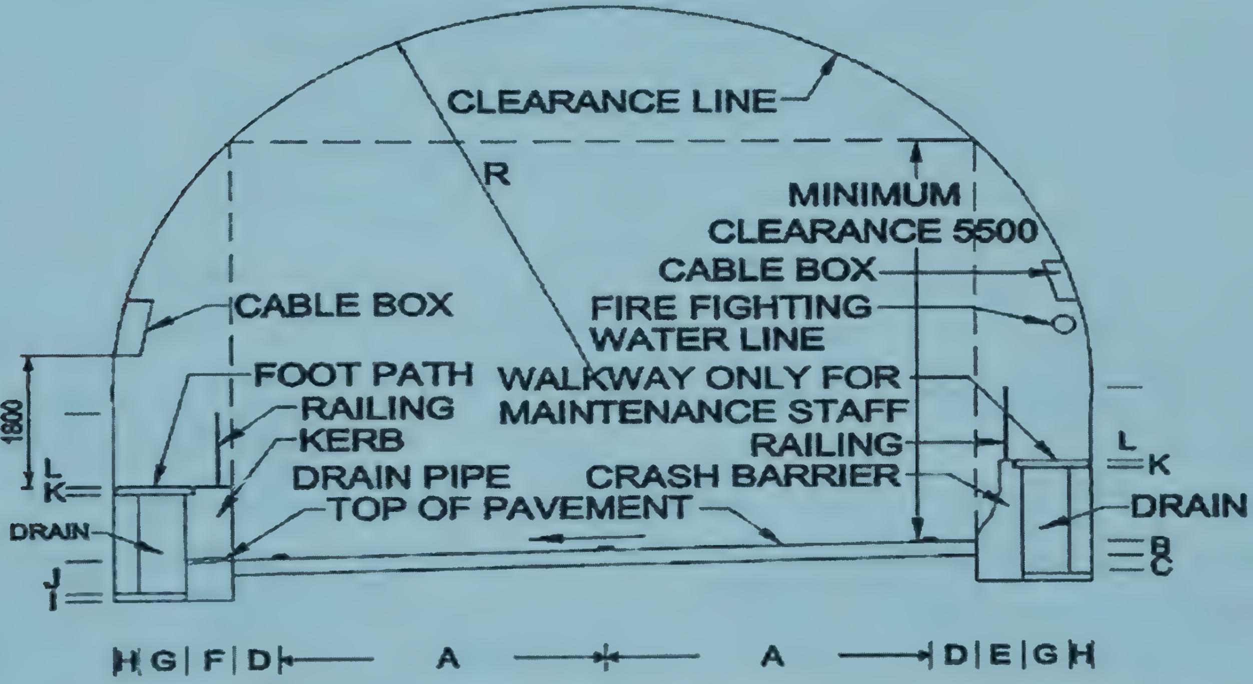

CLEARANCE LINE
R
MINIMUM CLEARANCE 5500
CABLE BOX
CABLE BOX
FIRE FIGHTING WATER LINE
1800
L
K
FOOT PATH
RAILING
KERB
DRAIN PIPE
TOP OF PAVEMENT
DRAIN
J
I
WALKWAY ONLY FOR MAINTENANCE STAFF
RAILING
CRASH BARRIER
L
K
DRAIN
B
C
H G F D A A D E G H

Fig. 11.2 Section of Two Lane Uni-Directional Traffic Tunnel

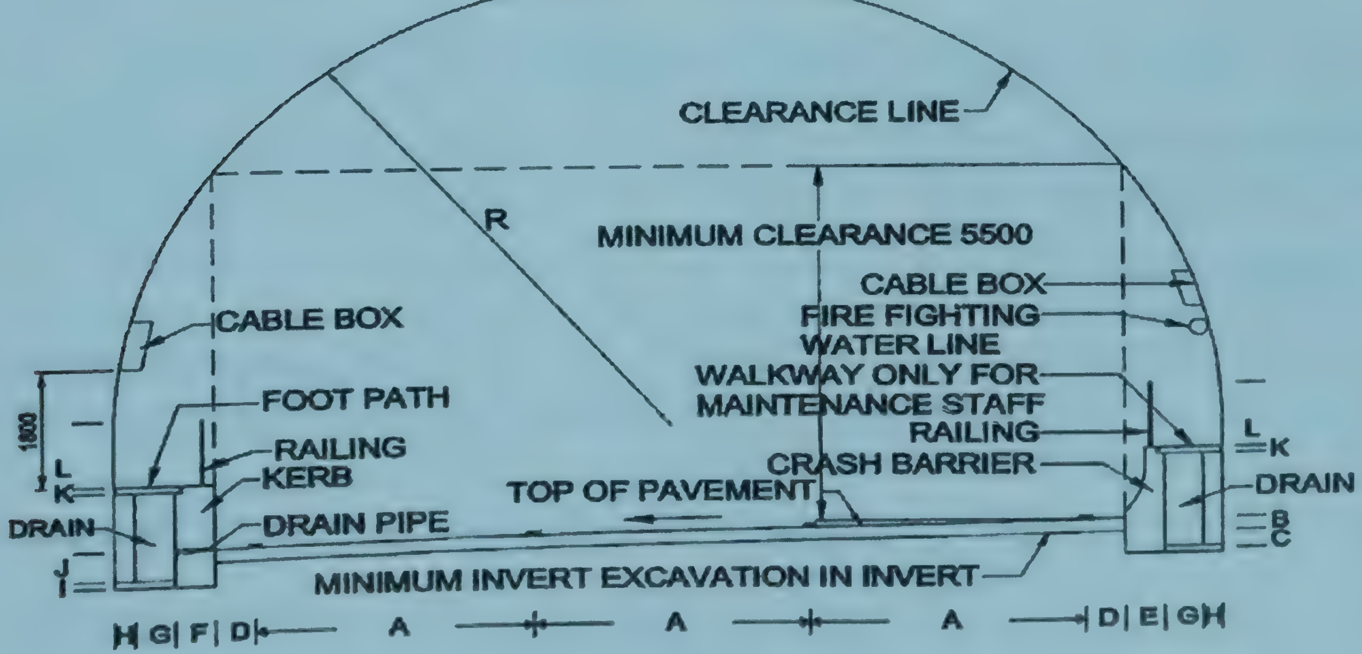

CLEARANCE LINE
R
MINIMUM CLEARANCE 5500
CABLE BOX
CABLE BOX
FIRE FIGHTING WATER LINE
WALKWAY ONLY FOR MAINTENANCE STAFF
RAILING
CRASH BARRIER
1800
L
K
FOOT PATH
RAILING
KERB
DRAIN PIPE
TOP OF PAVEMENT
DRAIN
J
I
L
K
DRAIN
B
C
MINIMUM INVERT EXCAVATION IN INVERT
H G F D A A A D E G H

Fig. 11.3 Section of Three Lane Uni-Directional Traffic Tunnel

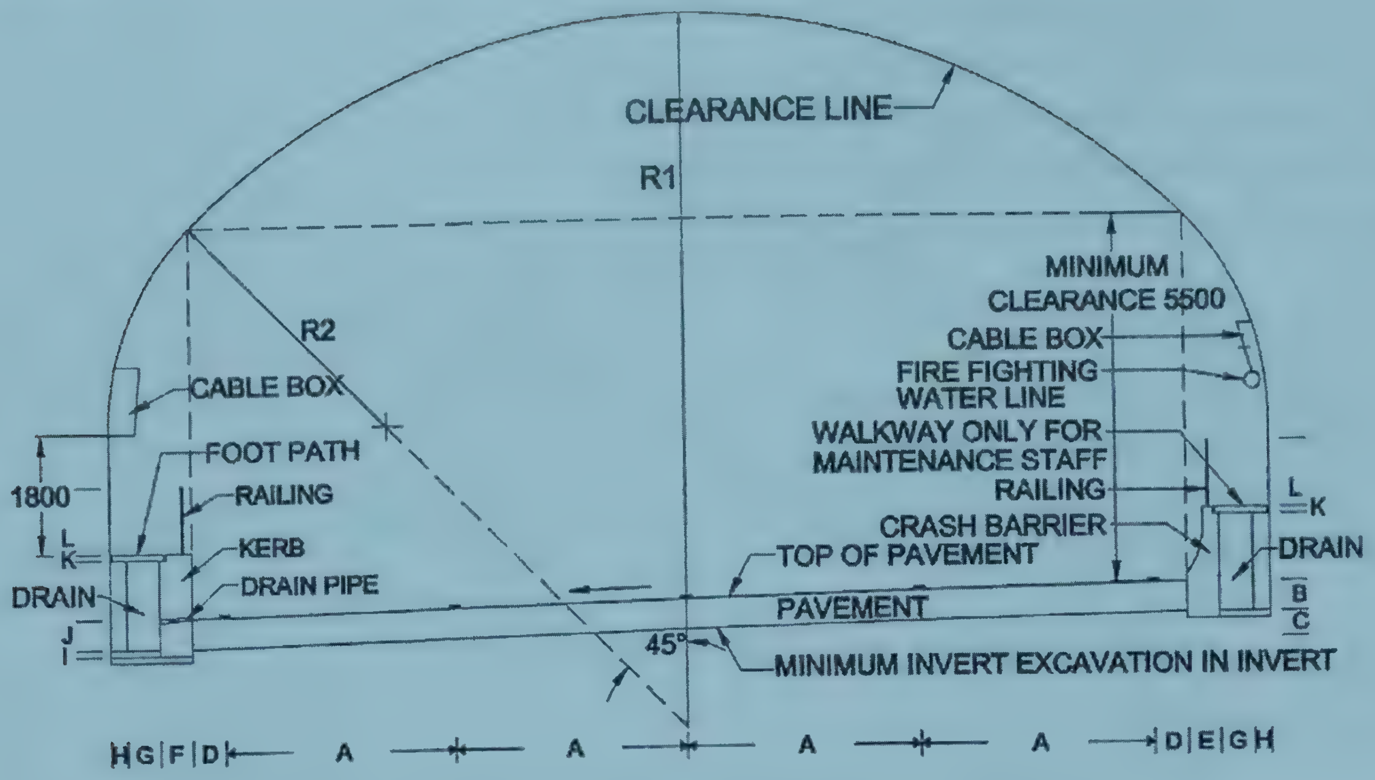

CLEARANCE LINE
R1
R2
MINIMUM CLEARANCE 5500
CABLE BOX
FIRE FIGHTING WATER LINE
WALKWAY ONLY FOR MAINTENANCE STAFF
RAILING
CRASH BARRIER
TOP OF PAVEMENT
PAVEMENT
DRAIN
CABLE BOX
FOOT PATH
RAILING
KERB
DRAIN PIPE
DRAIN
1800
L
K
J
I
B
C
45°
MINIMUM INVERT EXCAVATION IN INVERT
H G F D A A A A D E G H

Fig. 11.4 Section of Four Lane Uni-Directional Traffic Tunnel

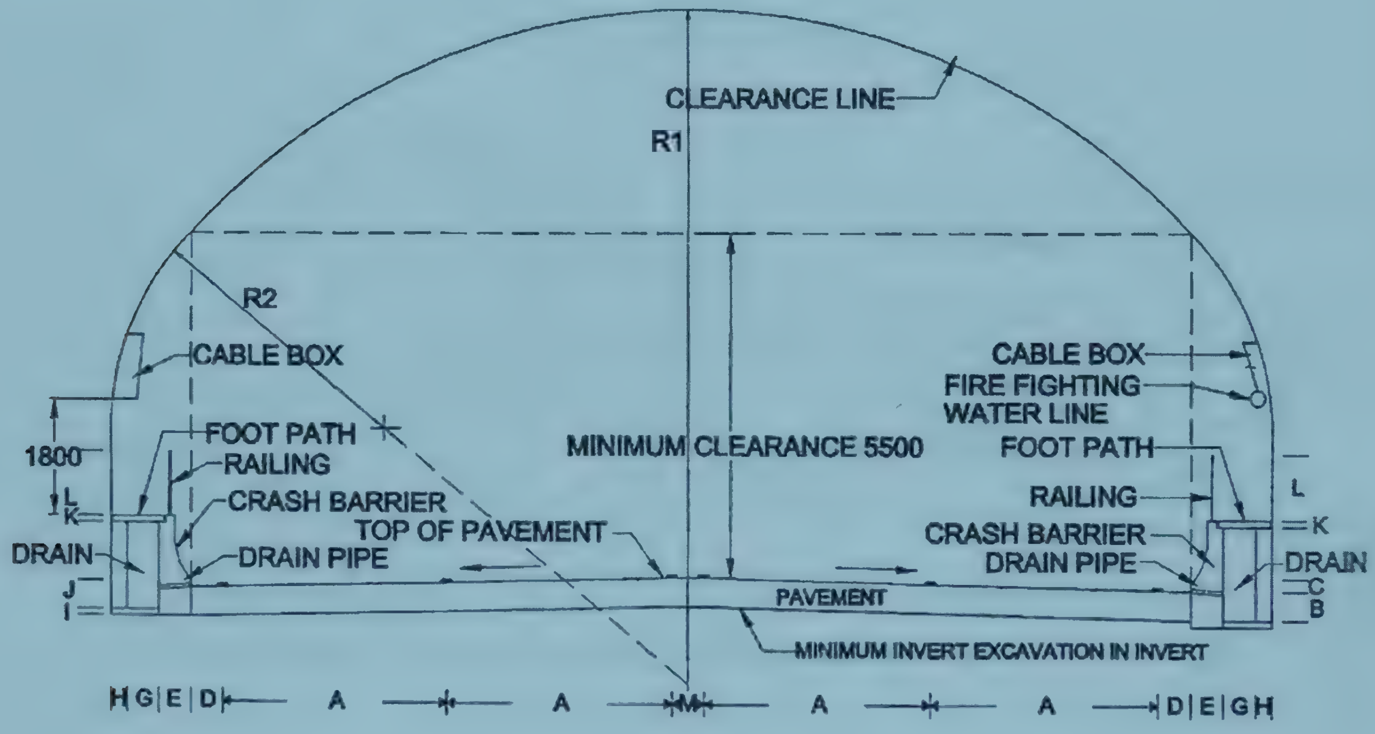

CLEARANCE LINE
R1
R2
CABLE BOX
FOOT PATH
RAILING
CRASH BARRIER
TOP OF PAVEMENT
DRAIN PIPE
DRAIN
1800
L
K
J
I
MINIMUM CLEARANCE 5500
CABLE BOX
FIRE FIGHTING WATER LINE
FOOT PATH
RAILING
CRASH BARRIER
DRAIN PIPE
DRAIN
C
B
PAVEMENT
MINIMUM INVERT EXCAVATION IN INVERT
H G E D A A M A A D E G H

Fig. 11.5 Section of Four Lane Bi-Directional Traffic Tunnel

Note: If geotechnical conditions prevent use of above section of 4 lane bi-directional Tunnel, two separate tunnels of two lane unidirectional cross section as per **Fig. 11.2** above shall be adopted.

11.5 Investigations

i) **Site Investigations:** Site investigations are conducted to select tunnel route, judge suitability of tunnel methods, size of the tunnel, and should cover local conditions along the tunnel alignment related to:

- Land usage and related property rights, including encumbrances and restrictions on surface/underground land usage.
- Future development plans along the route.
- Road classification and traffic conditions; to help in determining tunnel locations.

- Difficulty of land use for construction; e.g., construction yard etc.
- River, lake and sea conditions; including cross section, structure of its banks, etc.
- Availability and capacity of power, water and sewage connection for construction.
- Disposal of excavated materials including reutilization or disposal and location of disposal to be made clear.

ii) **Obstacles Investigations:** Obstacle investigation is conducted to identify inter alia the following items:

- Existing surface and underground structures; including foundation type, basements and nearby structures.
- Existing underground utilities.
- Bore Wells/Open Wells in use and abandoned wells to assess risk of blowout/ leakage of slurry etc.
- Sites of removed structures and temporary works, including contaminated soils and groundwater.

iii) **Geotechnical Investigations:** Geological and geotechnical investigation are conducted to determine topography; geological formations; soil conditions; and ground water. These form an important part of investigations for a tunnel option. IRC:SP:91 may be referred for details.

- Water Table

iv) **Investigations for Environmental Protection:** The following items should be investigated, as need arises, in order to protect the environment, during and after tunnel construction:

- Noise and Vibration should be monitored both prior to and during construction to evaluate those generated just by tunnel construction.
- Ground Movements: Condition of the ground and structures along the alignment should be surveyed and monitored, during and after construction, in order to quantify degree of ground heave subsidence and effect on structures along tunnel route.
- Groundwater: Wells and other water bodies, their water level and quality within the sphere of influence should be surveyed. Timing of survey and construction should be compared to account for seasonal fluctuation in groundwater level.
- Hazardous Gases: Such as methane; oxygen-deficient air resulting from oxidation of iron content and organic material in soil may be pushed into nearby wells and basements due to tunneling operations and possibility thereof needs to be investigated.
- Recycling: Recycling of construction byproducts e.g. rock etc. should be explored for preservation of the environment.
- Dumping yard for disposal of excavated materials need to be identified.

v) **Structural Design:** Structural design is required for:

- Deciding geometry of the excavated periphery of the tunnel.
- Design of tunnel supporting systems.

- Deciding on the minimum distance between adjacent tunnels. The services of domain experts need to be procured for this purpose.

11.6 Construction Methodology

Tunnels are constructed in soft ground or in rock and different methodologies are applied for these two cases. While tunnels could be constructed by boring, the cut and cover tunnel type is also commonly used in urban situations.

11.6.1 *Soft Ground Tunneling*

Soft ground requires support as soon as possible after excavation, in order to maintain stability of the excavation. In dense urban areas, limiting settlement is necessary in order to avoid damage to overlying structures. Control of groundwater is also important in soft ground tunneling. While groundwater above the water table increases stand-up time in granular soil, below the water table, it reduces effective strength, and seepage force can cause failure in such soil. In cohesive soils, groundwater determines strength, sensitivity and swelling properties, which control design of the final lining. Soft ground tunneling for long tunnels is done by Tunnel Boring Machines (TBM) although use of TBM for soft ground tunnels has not been in practice in India. Methods developed in Austria called variously 'New Austrian Tunneling Method' (NATM), 'Sequential Excavation Method'(SEM), and 'Sprayed Concrete Lining' are now common for tunnels in soft grounds. In soft ground tunneling, ground support must be placed immediately after excavation. As long as the ground is properly supported, NATM construction methods are appropriate for soft ground conditions. Dia from mault construction can also be considering minimizing construction time.

11.6.2 *Rock Tunnels*

Tunnels constructed in rock are more common and involve generally the drill and blast technique for tunnels. Use of equipment such as road headers (for relatively softer rocks) and tunnel boring machines (for long tunnels) is made for construction of tunnels in rock.

11.6.3 *Cut and Cover Tunnels*

Cut and Cover methods are adopted more commonly in soft grounds and sometimes even in rocky strata. The use of cut and cover method involves excavation in the ground and construction usually of a box type RCC structure with backfill. The design of such structures aims at resisting dead loads, live loads, loads of the ground fill over the structure, earth and water pressures, buoyancy etc. If significant uplift is expected due to buoyancy, tension piles or rock anchors are deployed to resist such uplift. One of the common issues faced in urban situations is the requirement of shoring and supporting the excavations. This is done by methods such as diaphragm walls, secant piles or similar shoring methods.

11.7 Ventilation

The design should control the level of vehicle emission contaminants within the roadway tunnel during normal tunnel operations, and should also control smoke and heated gases during fire emergencies. The design of the ventilation system should comply with the following general requirements:

i. Requirements on air quality;
ii. Requirements on discharge to the environment in the vicinity;
iii. Requirements on noise and vibrations;
iv. Requirements on visibility;
v. Requirements on protection against propagation of combustible gases and fire;
vi. Control of heat and smoke movement during a fire incident.
vii. Wind rose studies for short tunnels to be taken up.

The ventilation system may be based either on longitudinal ventilation or cross ventilation or a combination of these principles (so called semi cross ventilation). Longitudinal ventilation may be used in one-way traffic tunnels as also in two-way traffic tunnels. In long tunnels, where there is risk of congested traffic; air evacuation, or alternatively, air supply through ventilation chimneys may be needed along the tunnel. Longitudinal ventilation is inappropriate in two-way traffic tunnels that do not have separate emergency evacuation arrangements. When selecting a ventilation system and designing it, the fact that the necessary air flow rate may decrease in future should be taken into consideration; for example, as a result of reduced emissions from vehicles. Reduced air velocity in the tunnel and chimneys will affect the dispersion of pollution in the surrounding. The mechanical ventilation plant should generate the necessary air velocity for the design fire load and its duration. The entire ventilation system, as well as the associated components, should comply with the requirements on noise and vibrations.

11.8 Lighting

Geographic location, orientation, and portal surroundings influence the ability of the motorist to adapt from the bright ambient roadway to the dim tunnel interior. Lighting concepts are used to diminish the contrast between the two environments; the most prominent lighting concepts used are the symmetrical and the asymmetrical concepts, of which there are two types - the counter beam and the line-of-sight. Linear or point source luminaries, or a combination of types of sources are employed to provide specific illumination requirements for unidirectional or bidirectional traffic tunnels, as appropriate to the system.

11.9 Safety during Construction

i) Working in tunnels is risk prone. The employer and the supervision engineer should ensure that the contractor has put in place a well laid down Project Safety Plan for the construction personnel (site staff, workers, equipment operators, etc) and the users. The plan should be formulated keeping in view the labour laws and regulations as well as the broader aspects of Safety, Health and Environment (SHE) policy

ii) Other regulations are:
    i) Indian Explosives Act, 1884 and Explosives Rules 1983
    ii) Mines Act, 1952 and Mines Rules 1955
    iii) IS:4081-1986 – Safety Code for Blasting and related Drilling Operations
    iv) IS:4756-1978 – Safety Code for Tunnelling Works

iii) All personnel to wear the relevant Personnel Protective Equipment (PPE) such as safety helmet, safety shoes, tight clothing/jackets with reflective stripes. Additional

PPE such as goggles, gloves, dust masks, helmet lamps shall also be worn where conditions so warrant.

iv) The personnel of the contractor and his subcontractors shall practice all standard safety systems and requirements. The Contractor shall arrange awareness raising programmes on such requirements from time to time. Medical screening of personnel may also be undertaken.

v) Suitable arrangements should also be made for transmitting of warning signals and protection against fire and other hazards.

11.10 Operation and Maintenance

The operation and maintenance shall be planned to achieve the following objectives:

- Safety of road users
- Reasonably free flow of traffic
- Operational economy
- Readiness for emergency situations.

Normal operations shall cover maintenance of tunnel structure, equipments, installations and deployment of rescue vehicles, ambulance, signal and communication facilities and fire-fighting equipment.

11.11 Some Case Studies

i) Anik Panjarapol Tunnels: The twin tube tunnels approximately 500m long were provided on the Anik Panjarapol Road (portion of the Eastern Freeway in Mumbai) where the road passed through the hill near Trombay. The tunnels were constructed by drill and blast method and comprised a section. The rock obtained from excavation was crushed and used for concrete. The road inside the tunnel comprised four lanes each with footpaths for maintenance. The open cut on both sides were provided with rock bolts and shotcrete to prevent rock falls on the moving traffic below. One of the open cuts on the Panjarapol side was 30m high and comprised relatively softer rock. To prevent landslide and slope failure in this rock, deep passive rock anchors were provided with shotcrete on the gently sloping rock face.

ii) Tunnel connecting Western Express Highway to Sahar Elevated Road : The Western Express Highway in Mumbai connects to the Sahar Elevated Road leading to the International Airport Terminal 2 through a tunnel. This Cut and Cover Tunnel was constructed by providing secant piles for shoring along the walls of the tunnel. In the portion which lay below the Western Express Highway, a deck slab was provided spanning over the secant pile walls. Excavation was carried out under the slab to provide opening for the tunnel with traffic allowed over the slab to relieve congestion during construction.

CHAPTER 12

QUALITY CONTROL IN CONSTRUCTION

12.1 Introduction

Quality is considered as conformance to Specifications and Standards prescribed. The quality control is an essential requirement for construction of various components of urban roads and streets by adopting BIS/IRC/MoRTH Specifications and construction methods for creating durable assets. The overall quality control must cover both the quality of materials and workmanship at site with the help of objective tests performed at a reasonable, pre-determined frequency without affecting progress of works.

For details on quality control of road projects, refer to IRC:SP:112 "Manual for Quality Control in Road and Bridge Works" and Section 900 and relevant sections for various components of roads and bridges of the "MoRTH Specifications for Road and Bridge Works". As regards bridge works, tests and acceptance standards for various aspects and components are described in relevant sections of these Specifications.

12.2 Pre-Requisite

Pre-requisites for quality control shall be as follows:

i) All materials to be used, all methods to be adopted and all works performed shall be strictly in accordance with the requirement of specifications.

ii) The contractor shall set-up fully furnished and adequately equipped field laboratory. The laboratory shall preferably be located near the site office as approved by the Engineer-in-Charge and provided with amenities like water supply, electric supply etc. For conducting other required tests, arrangements may be made with other organizations/laboratories also to meet the requirements of quality control and quality assurance. The list of equipment and the quality control facilities shall be got approved from Engineer-in-Charge in advance before start of work. The laboratory shall be manned by a qualified Materials Engineer/Scientist assisted by experienced Laboratory Assistants/Technicians. The items of laboratory equipment shall be provided in the field laboratory and at the plant site depending upon the items to be executed as per MoRTH Specifications and guidelines contained in IRC:SP:112.

iii) The contractor shall arrange field laboratory building and equipment and the same shall be the property of the Contractor. The Employer and the Engineer shall have free access to the laboratory. The Project Manager and Site Engineers of the Contractor (and his Sub Contractors); and the team of Consultants to whom supervision of work is entrusted should have thorough knowledge of the following documents (latest versions):

    a) MoRTH Specifications for Road and Bridge Works
    b) Specifications as laid down by Urban Local Bodies
    c) BIS codes and tests
    d) IRC Publications on Quality Assurance and Quality Control for Road Projects including IRC:SP:112 (Manual for Quality Control in Road and Bridge Works)
    e) Any other code or document forming part of contract

12.3 Earth Work (Embankment and Subgrade Materials)

For construction of the embankment and the subgrade, the materials should satisfy the density requirements given in Table 300-1 of MoRTH Specifications for Road and Bridge Works, 2013 reproduced in **Table 12.1**.

Table 12.1 Density Requirements of Embankment and Sub-grade Materials

S. No.	Type of Work	Maximum laboratory dry unit weight when tested as per IS:2720 (Part 8)
1	Embankments up to 3m height, not subjected to extensive flooding	Not less than 15.2 kN/cum
2	Embankments exceeding 3m height or embankments of any height subject to long periods of inundation	Not less than 16.0 kN/cum
3	Subgrade and earthen shoulders/verges/ backfill	Not less than 17.5 kN/cum

Note: 1) This Table is not applicable for lightweight fill material, e.g., cinder, fly ash, etc.

2) The material to be used in subgrade shall be non-expansive and shall satisfy design CBR at the specified dry density and moisture content. In case the available materials fail to meet the requirement of CBR, use of stabilization methods in accordance with Clauses 403 and 404 or by any stabilization method approved by the Engineer shall be followed.

The compaction requirements shall meet the standards laid down in Table 300-2 of MoRTH Specifications for Road and Bridge Works, 2013 reproduced in **Table 12.2**.

Table 12.2 Compaction Requirements for Embankment and Sub-grade

S. No.	Type of work/material	Relative compaction as percentage of max. laboratory dry density as per IS:2720 (Part-8)
1	Subgrade and earthen shoulders	Not less than 97 %
2	Embankment	Not less than 95%
3	Expansive Clays	
	i) Subgrade and 500mm portion just below the subgrade	Not allowed
	ii) Remaining portion of embankment	90-95%

12.4 Granular Sub-bases (GSB)

The material to be used in GSB layer shall be natural sand, crushed gravel, crushed stone, crushed slag, reclaimed asphalt materials, and demolished concrete aggregates or combination of these materials depending upon the required grading. Use of kankar, moorum, brick metal and crushed concrete may be permitted in the lower sub-base subject to fulfilment of grading requirements given in Table 400-1 and the physical requirements for materials given in Table 400-2 of MoRTH Specifications for Road and Bridge Works, 2013 reproduced in **Tables 12.3** and **12.4**.

Table 12.3 Grading for Granular Sub-base Materials

IS Sieve Designation (mm)	Percent by Weight Passing the IS Sieve					
	Grading-I	Grading- II	Grading- III	Grading- IV	Grading- V	Grading- VI
75.00	100	-	-	-	100	-
53.00	80-100	100	100	100	80-100	100
26.50	55-90	70-100	55-75	50-80	55-90	75-100
9.50	35-65	50-80	-	-	35-65	55-75
4.75	25-55	40-65	10-30	15-35	25-50	30-55
2.36	20-40	30-50	-	-	10-20	10-25
0.85	-	-	-	-	2-10	-
0.425	10-15	10-15	-	-	0-5	0-8
0.075	< 5	< 5	< 5	<5	-	0-3

Table 12.4 Physical Requirements for Materials for Granular Sub-base

Tests	Relevant Standard Codes	Specification Limits
Aggregate Impact Value (AIV)	IS:2386 (Part 4) or IS:5640	40 Maximum
Liquid Limit	IS:2720 (Part 5)	25 Maximum
Plasticity Index	IS:2720 (Part 5)	6 Maximum
CBR at 98% dry density (at IS:2720-Part 8)	IS:2720 (Part 5)	Minimum 30 unless otherwise specified in the contract

12.5 Wet Mix Macadam

Materials used shall be clean, crushed, graded aggregate, reclaimed asphalt materials, and demolished concrete aggregates and granular material with little fines, premixed with water, to a dense compacted granular sub-base. The physical and grading requirements shall be as per Table 400-12 and Table 400-13 of MoRTH Specifications for Road and Bridge Works, 2013 reproduced in **Tables 12.5** and **12.6**.

Table 12.5 Physical Requirements of Aggregates

S. No.	Test	Test Method	Requirements
1	Los Angeles Abrasion Value or	IS:2386 (Part 4)	40% Maximum
	Aggregate Impact Value	IS:2386 (Part 4) or IS:5640	30% Maximum
2	Combined Flakiness and Elongation Indices (Total)	IS:2386 (Part 1)	35% Maximum*

Note:* To determine this combined proportion, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone sample. Only the elongated particles be separated out from the remaining (non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The values of flakiness index and elongation index so found are added up

Table 12.6 Grading Requirements of Aggregates for Wet Mix Macadam

IS Sieve Designation	Percent by Weight Passing the IS Sieve
53.00 mm	100
45.00 mm	95-100
26.50 mm	–
22.40 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600.00 micron	8-22
75.00 micron	0-5

Note: Material finer than 425 micron shall have Plasticity Index (PI) not exceeding 6.

12.6 Bituminous Bound Bases and Surface Courses

The dense graded bituminous mixes are Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC). The physical requirements of aggregates used in dense graded mixes shall be as per **Table 12.7** (combined for DBM and BC) extracted from Table 500-8 and Table 500-16 of MoRTH Specifications for Road and Bridge Works, 2013. The gradation composition of DBM and BC shall be as per **Tables 12.8** and **12.9** which has been reproduced from Table 500-10 and Table 500-17 of MoRTH Specifications for Road and Bridge Works, 2013. The requirement of mix design for dense graded bituminous mixes has been given in **Tables 12.10** and **12.11** which has been reproduced from Table 500-11 and Table 500-12 of MoRTH Specifications for Road and Bridge Works, 2013. However, the dense bituminous pavement gradations shall be constructed in accordance with the Section 500 of MoRTH Specifications for Road and Bridge Works, 2013.

Table 12.7 Physical Requirements of Aggregates

Property	Test	Specification	Method of Test
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 micron	IS:2386 Part I
Particle Shape	Combined Flakiness & Elongation Indices*	Max 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value or	BC-Max 30% DBM-Max 35%	IS:2386 Part IV
	Aggregate Impact Value	BC-Max 24% DBM-Max 27%	
Durability	Soundness either: Sodium Sulphate or	Max 12%	IS:2386 Part V
	Magnesium Sulpahte	Max 18%	
Polishing (Only for BC)	Polished Stone Value	Min 55	BS:812-114
Water absorption	Water absorption	Max 2%	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Min retained coating 95%	IS:6241
Water sensitivity	Retained Tensile Strength**	Min 80%	AASHTO 283

* To determine the combined proportion, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone

sample. Only the elongated particles be separated out from the remaining (non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The values of flakiness index and elongation index so found are added up.

** If the minimum retained tensile strength falls below 80 percent, use of anti stripping agent is recommended to meet the requirement.

Table 12.8 Composition of Dense Graded Bituminous Macadam

Grading	1	2
Nominal Aggregate Size*	37.5 mm	26.5 mm
Layer Thickness	75-100 mm	50-75 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
45.0	100	-
37.5	95-100	100
26.5	63-93	90-100
19.0	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen content per cent by mass of total mix**	Min 4.0**	Min 4.5**

* The nominal maximum aggregate size is the largest specified sieve size upon which any of the aggregate is retained.

** Corresponds to specific gravity of the aggregate being 2.7. In case aggregate have specific gravity more than 2.7, the minimum bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily mean air temperature is -10°C or lower, the bitumen content may be increased by 0.5 percent.

Table 12.9 Composition of Bituminous Concrete Pavement Layers

Grading	1	2
Nominal Aggregate Size*	19 mm	13.2 mm
Layer Thickness	50 mm	30 - 40 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
26.5	100	-
19	90-100	100
13.2	59-79	90-100
9.5	52-72	70-88

Grading	1	2
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.60	15-27	26-38
0.30	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content per cent by mass of total mix**	Min 5.2	Min 5.4

* The nominal maximum aggregate size is the largest specified sieve size upon which any of the aggregate is retained.

** Corresponds to specific gravity of the aggregate being 2.7. In case aggregate have specific gravity more than 2.7, the minimum bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily mean air temperature is -10°C or lower, the bitumen content may be increased by 0.5 percent.

Table 12.10 Requirements of Mix Design for Dense Graded Bituminous Mix

Properties	Viscosity Grade Paving Bitumen	Modified Bitumen		Test Method
		Hot Climate	Cold Climate	
Compaction level	75 blows on each face of the specimen			
Minimum Stability (kN at 60 °C)	9	12	10	AASHTO T245
Marshall flow (mm)	2 - 4	2.5 - 4	3.5 - 5	AASHTO T245
Marshall Quotient (Stability/Flow)	2 - 5	2.5 - 5		MS-2 and ASTM D2041
% Air Voids	3 - 5			-
% Voids filled with Bitumen (VFB)	65 - 75			-
Coating of aggregate particles	95% (Minimum)			IS:6241
Tensile Strength Ratio	80% (Minimum)			AASHTO T283
% Voids in Mineral Aggregate (VMA)	Minimum percent voids in mineral aggregate (VMA) are set out in **Table 12.11**			-

Table 12.11 Minimum Percent Voids in Mineral Aggregate (VMA)

Nominal Maximum Particle Size (mm)	Minimum % VMA Related to Designed % Air Voids		
	3.0	4.0	5.0
26.5	11.0	12.0	13.0
37.5	10.0	11.0	12.0

Note: Interpolate minimum voids in the mineral aggregate (VMA) for designed percentage air voids values between those listed.

12.6.1 *Bituminous Surfacing for Low Volume Roads*

In case of low volume roads such as collector or sub-collector roads where the total commercial vehicles are less than 2 msa, the close-graded Premix Surfacing (PMC) or Mixed Seal Surfacing (MSS) shall be used as wearing course. The details as given in Section 508 of MoRTH Specifications for Road and Bridge Works, 2013 should be followed. The aggregate gradation requirements given in the MoRTH Specifications, 2013 (Table 500-19) are being reproduced here and given in **Table 12.12**.

Table 12.12 Aggregate Gradation for Close Graded PMC/MSS

IS Sieve Designation (mm)	Cumulative Percent by Weight of Total Aggregate Passing	
	Type A	Type B
13.2	-	100
11.2	100	88-100
5.6	52-88	31-52
2.8	14-38	5-25
0.09	0-5	0-5

Note: Type A grading is recommended for use in areas having rainfall more than 150 cm per year whereas Type B grading may be used in other areas.

12.7 Cement Concrete Pavements

The cement concrete pavements shall be constructed in accordance with the Section 600 of MoRTH Specifications for Road and Bridge Works, 2013 and IRC:15 'Code of Practice for Construction of Jointed Plain Concrete Pavements'.

12.8 Recycling of Bituminous Pavements

Where foamed bitumen is used as recycling agent, the quality control requirements shall be as per Appendix II to Annex 1 of IRC:120-2015. The Quality Requirements (Mechanical properties and frequency of test shall be as per **Table 12.13**.

Table 12.13 Quality Requirements

Material/ Structure	Test	Test Method	Quantity	No of test (minimum)
Bitumen	Penetration grade Foaming characteristics	Delivery ticket Visual *	Per tanker	1
Bitumen stabilized layer	Layer thickness	Measurements	Completed Layer**	-
	Compaction	IS 2720 (Part 28)	Batch (note 1)	4

Material/ Structure	Test	Test Method	Quantity	No of test (minimum)
Foamed bitumen stabilized material	Moisture content determination	IS 2720 (Part 2)	Batch (note 1)	4
	Moisture/density relationship	IS 2720 (Part 8)	Batch (note 1)	1
	Strength characteristics	ITS***	Batch (note 1)	2

Note 1: A Batch shall constitute a day's work or as determined by the Engineer.

* Delivery ticket is the part of the bitumen delivery process. To check the foaming characteristics of each tanker-load of bitumen that is consumed, the test nozzle on the in-situ recycler or in-plant mixer shall be used. A quantity of foamed bitumen is injected from the test nozzle into a straight-sided container (normally a 5-second sample). The half-life is measured by taking the time for the foamed bitumen to reduce in volume to half the height of the maximum expansion noted in the container. The container is then set aside for at least 30 minutes or until the foamed bitumen has subsided completely and the unexpanded volume of the quantity of bitumen injected into the container is noted. The expansion ratio is the ratio of the maximum expansion to the unexpanded volume where the unexpanded volume is taken as one unit.

** The thickness of the completed layer shall be determined at each density test location from physical measurements of the excavated hole. In addition, 100 mm diameter cores may be extracted and measured after a curing period of at least two weeks.

***

Strength Test	Specimen diameter	Minimum strength
ITS_{dry} 25°C	100mm	> 225 kPA
ITS_{wet} 25°C	100mm	> 100 kPA

12.9 Tests and their Frequencies

It is important that the works for each layer and each component conform to the requirements of the specifications and standards and the same is verified prior to taking up the next layer/ component. In case of road works, each layer shall be put to tests as per Section 900 of MoRTH Specifications for Road and Bridge Works, 2013. As regards bridge works, reference may be made to relevant sections of these Specifications.

12.10 Rectification of Deficiencies

After satisfying with the quality of work, both the material inputs and workmanship, the works are accepted. However, where deficiencies are noticed, the contractors shall be directed to undertake rectification measures and report compliance, otherwise the work shall stand rejected. For details, refer MoRTH Specifications for Road and Bridge Works, 2013 and IRC:SP:112 "Manual for Quality Control in Road and Bridge Works".

CHAPTER 13

ENVIRONMENTAL AND SOCIAL SAFEGUARDS

13.1 Introduction

Road development, while promoting economic growth has environmental and social impacts. Each kilometre of road requires large quantities of rock, concrete, asphalt and steel to be sourced, transported and placed. Road aggregates being one of the most mined resources, have environmental consequences. Further, roads can result in the displacement of communities, which are located along the planned alignment, thereby hampering their employment and social networks.

Further, due to global warming, infrastructure development will become more vulnerable to extreme weather events. Increased temperature, heat islands in cities, and extreme weather events like floods, sea level rise and storm surge, coastal erosion, drought and change in soil moisture will damage road infrastructure. For example, coastal cities will be susceptible to sea level rise and extreme floods as their low lying areas would be submerged. With salt water intrusion, shrinking of wetlands and tidal flooding, existing infrastructure in vulnerable areas will be at high risk. The case of floods in Chennai (**Box 13.1**) revealed how building activities in low lying areas disturbed the natural water drainage systems and made the city vulnerable to floods. Similarly, hills are likely to experience more landslides that will impact roads and therefore accessibility. Therefore, it is crucial to guide road network planning, design and construction to enable economic growth, along with environmental and social sustainability and climate resilience.

Box 13.1 Increased Vulnerability to Extreme Weather Events - Case of Chennai Floods

In 2015, Chennai experienced 450 mm rain in 7 days, and more than 1200 mm in November 2015 (**Fig. 13.1**). Chennai had more than 600 water bodies in the 1980s but the Master Plan of 2008 stated that only a few were in proper condition. Area of 19 major lakes has shrunk from a total of 1,130 hectares in the 1980s to nearly 645 hectares in early 2000s, reducing their storage capacity.

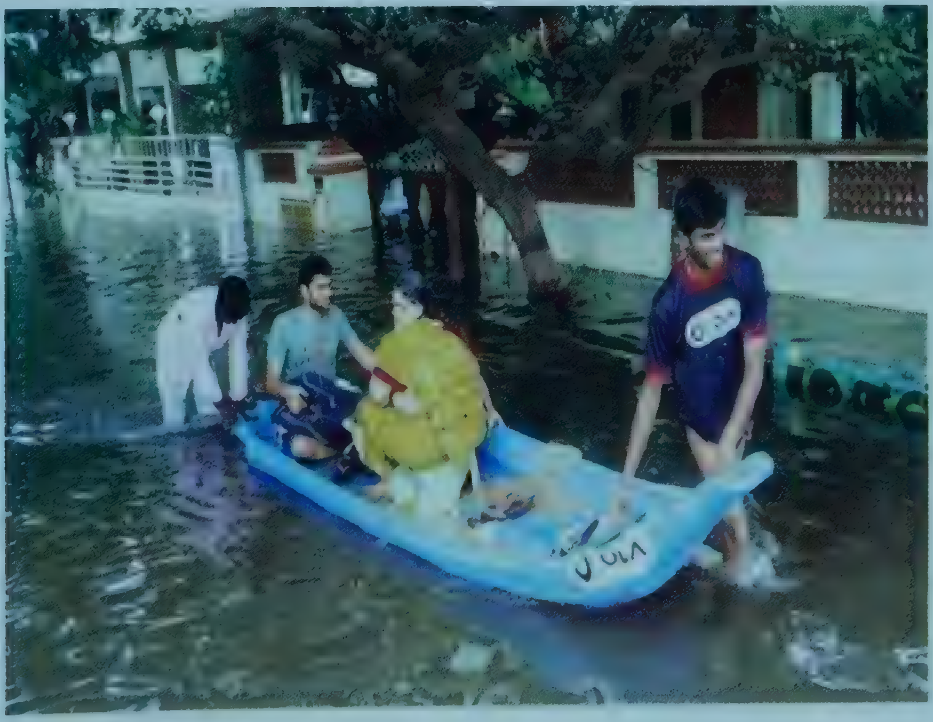


Fig. 13.1 Roads Flooded during Chennai Floods

New and existing roads should aim to prevent environmental degradation and resource depletion, facilitate safe access, minimize ecological footprints, displacement of communities and their economic and social networks. Therefore, these aspects need explicit recognition in road planning, design and construction guidelines.

13.2 Environmental Impacts of Roads

Emissions of heat trapping and polluting gases related to road building: The emissions from mining, transportation, earthworks and paving associated with road construction, as well as emissions from increased private motor vehicle use make roads and road transport as one of the major contributors to carbon dioxide emissions and pollution. Mitigation is needed not only in the process and materials of road design, but also during construction and maintenance.

Toxic impact of road building material on water resource, natural drainage system and soil quality: The environmental impact of road construction materials is influenced by the choice of materials and the processes through which those materials are sourced, transported and used to construct roads. The materials used for road construction affect the surrounding environment due to toxicity through leachate and surface runoff. Damage due to soil erosion affects soil quality and fertility. The construction of road also affects the natural drain networks and watershed zones. If not planned properly, it can lead to water logging and floods. It also results in reduced water percolation due to surface run-off thereby reducing the water table and groundwater reserves. Extensive road circulation systems have profound impact on natural drainage systems, urban green and open spaces and natural water storage systems in cities. Special efforts are needed to identify environmentally optimised design solutions. Ecological footprint of roads can be reduced by optimising route alignment, managing storm water runoff and controlling erosion.

Road excavation and road operations are source of enormous dust pollution: Road dust is as much as 38 per cent of the PM 2.5 in Delhi (IIT Kanpur, 2016). Both structural and maintenance solutions are needed to address this concern. It is important to balance earthworks to optimise cut and fill and ensure effective scheduling and rapid delivery. Road design also requires dust dousing features like vegetative barrier and appropriate paving and good maintenance in post construction phase.

Impact of roads on biodiversity and wildlife habitat and species: The toxic emissions during road construction and operations have an adverse effect on the surrounding biodiversity. Increased pollution and temperatures endanger many wildlife species and their habitats. It affects the density and composition of wildlife species and population.

Impact of roads on communities: The planning and construction of road often results in displacement of communities that come in between the planned alignment. The displacement results in disruptions of economic and social networks of communities as they are forced to move to distant places. This results in increased travel for work and other social amenities.

13.3 Prevention and Mitigation Measures

It is important to plan for measures that prevent and help infrastructure mitigate different climate and natural risks. It is necessary to undertake risk and vulnerability mapping in different ecological zones including coastal regions, hills and also land locked plains that will become extremely critical to prevent and mitigate risk. To mitigate environmental impacts of road building, it is important to take eco sensitive approach for different geographical zones such as coasts, river flood plains and low lying areas, hills, and semi-arid areas. Each one of them has its own challenges and will require specific solutions. For instance, several cities in India are in the flood plains and prone to extreme floods. But, there are also semi-arid areas that will have to cope with heat effects but also short duration intense floods. Hill towns have other challenges like flash floods, landslides and heavy snowfall which make the land transport vulnerable. Several laws have been enacted for vulnerable areas like coastal zone regulations, eco sensitive zones etc.

Mitigation strategies can operate at three levels:

- At the planning level, activities can include revising master plans (for example, for land use, transportation networks etc) to facilitate land-use and transport integration and reflect any significant changes in landscape (for example, sea level, low lying areas or coastal zones) and natural resources (for example, water bodies, wetlands), as well as related climate risks. Other related actions might include formulating policies and development of new strategies.
- With respect to long-term investments, cities can decide to invest in infrastructure to mitigate climate change, such as sea wall or improved road network in a highly populated floodplain. These actions are more challenging to implement because they often demand substantial financial investments. In many instances, climate change adaptation alone may not be a sufficient rationale to justify an investment in a given location. However, when it is combined with possible benefits for every stakeholder and other considerations such as sustainable transportation, livelihood enhancement, tourism development, these investments can become financially feasible.
- At the operational level, climate change considerations can be integrated into municipal operations and service delivery. These actions can include responses to extreme weather events, such as closing certain roads and rerouting traffic, or adaptations to incremental change, such as painting bus roofs white to reflect heat during periods of more extreme summer temperatures.

13.3.1 *Promote Land-use and Transport Integration*

Urban planning encouraging sprawl results in increased transportation networks for connectivity and accessibility. This increases trip lengths and travel time. The derived street network due to such planning promotes increased use of personal motorized vehicles and discourages the use of NMVs. This results in increase in emissions, energy intensity of travel and productivity loss that eventually leads to pollution and other environmental problems. Such structural changes once done cannot be reversed easily and locks in enormous pollution load over time.

Urban and transport planning promoting compact cities with mixed and integrated land uses help in reducing the impact of road design and engineering on environment. The emission from different transport modes shall also reduce considerably. New road networks and the existing ones should be augmented to promote public transport and use of NMVs. This shall help in reducing emissions and promoting a healthy living environment.

13.3.2 *Conduct Environment and Social Impact Assessments*

Road projects are subject to environmental impact assessment during feasibility studies and preparation of Detailed Project Reports. Such an assessment should culminate into an environment management plan to define a clear set of actions and timelines, agencies and persons responsible. Urban Local Bodies need to ensure that budgets are allocated for these activities.

Substantial time and effort is often required to address potential impacts and ways to minimise them, to consult with various stakeholders who have an interest in the project, and to develop and implement mitigation plans. In addition, contract clauses elaborating work procedures and staff training needs to be prepared, and work processes in relation to roadside communities, flora, and fauna given attention. In order to conduct environment assessment successfully, road agency staff need to understand the assessment process and must coordinate it with road planning, design, and construction activities, allowing sufficient lead time and funds.

Similarly, social impact assessments evaluate the impact of infrastructure on surrounding communities. Such an assessment helps in understanding the number of families likely to be displaced and resettled, assess compensation for project affected persons, gauge communities' demand for amenities and facilities, and prepare a resettlement and rehabilitation plan to minimize hardships for displaced households and facilitate convenient access to economic and social opportunities. New arterial roads, urban bypasses and road widening projects must accompany a resettlement and rehabilitation plan. A follow-up assessment is recommended, after 2 years of project implementation, to monitor and evaluate the economic and social status of affected persons before and after the project.

13.3.3 *Ecologically Sensitive Zones and Biodiversity Rich Areas*

Urban roads and road alignments through ecological sensitive areas such as wild life and national parks, biodiversity parks, fragile high altitude eco systems, wetlands, coastal areas and shore line can have severe disruptive impacts on ecosystems. This will require careful mitigation and control measures. Environment impact assessment of a project in such zones has to be conducted in order to understand the environmental repercussions and feasibility.

Several approaches are being considered to harmonise the needs of wild life and road building in sensitive areas. For example, these may require well designed culverts under roads to allow wildlife crossing and migration. Put barrier along the road to guide animals to the culverts for safe passage. Culvert design is important that may require gravel or vegetation and not concrete. For larger animals, overpass will be needed with planted vegetation to mimic natural habitat. Roads may have to be closed and routes realigned during specific migration and breeding seasons of species, as applicable.

13.3.4 *Encourage Low Carbon Transport*

Road design will have to respond and adapt to changing uses and increase in travel volumes, especially greater demand for public and active (cycling and walking) transport. This is inevitable in climate, energy and pollution constrained situation (**Box 13.2**).

Box 13.2 Case Studies: Promoting Cycle Transportation

Some global cities have already started to make this transition. Copenhagen has been successful in prioritising non-motorised transport networks by investing heavily in cycle infrastructure and tailoring roads and transport policy to cyclists' needs since the 1970s. Cycling as a mode of transportation is growing in popularity among several cities. This is efficient, zero carbon and convenient. A 2014 study by the Municipality of Copenhagen, found that 45 per cent of the total number of people in the Danish capital cycled to their place of work or education. This has reduced air pollution and healthcare costs.

Singapore plans to build a cycling network spanning more than 700 km by 2030 to encourage cycling as an alternative mode of transport for short-distance commutes. The government is investing in cycling infrastructure, such as bicycle tracks, bicycle crossings and adequate lighting. The government is developing a cycling code of conduct to make cycling convenient and safe. Singapore has National Cycling Plan for comprehensive cycling networks for residents to cycle safely from their homes to major transport hubs and key amenities within their town.

13.3.5 *Integrate Adaptation Measures with Engineering Specifications*

With climate change, extreme weather events such as high intensity rains, storm surge and floods etc. will make road infrastructure increasingly more vulnerable with serious public health consequences. Climate resilient design standards and material will be needed for road infrastructure. There is need for detailed mapping of high risk areas. **Table 13.1** gives mitigation measures proposed. **Box 13.3** captures some international initiatives. Pilots can be attempted with guidance from domain experts.

Table 13.1 Impact of Climate Change and Mitigation Approaches

Climate Change Impacts	Impact on Road Infrastructure	Possible Mitigation Measures through Design and Material
High temperature and heat waves	• Deformation • Melting of asphalts • Rutting	• Road side plantation to provide shade and reduce exposure to heat. • Cooling through parks and lakes, preserving water bodies • More rut resistant asphalt • Improved and regular maintenance
Extreme rainfall and flooding	• High risk in low lying areas • Overloaded drainage or non-existent drainage and flooding will affect structural integrity due to erosion and high soil moisture	• Improve and augment drainage capacity and link with water storage and recharge • Audit drains infrastructure • Create flood map to protect infrastructure • Need alternative routes and evacuation plan • Flood risk assessment and flood plain management and coastal zone management.

Climate Change Impacts	Impact on Road Infrastructure	Possible Mitigation Measures through Design and Material
	• Flooding of subterranean tunnel.	• Install early warning systems • Install road signages especially in unsafe low lying areas • Improve green spaces for flood protection • Monitor sub-grade material • Use more durable and corrosion free material
Drought and variable soil moisture	• Road foundation degradation due to increased variation in wet/dry spell and decrease in availability in moisture • Road dust is safety hazard due to reduced friction in braking • Poor sighting of roadway marking	• Need risk mapping and monitoring of soil moisture • Avoid new development in high risk areas • Improved maintenance
Sea level rise and coastal erosion	• Inundation and flooding especially that of underground tunnel • Degradation of roadway surface, base layers from salt penetration	• Create vulnerability map • Need zoning to restrict development along shore line and other vulnerable areas • Integrate transport planning with coastal zone management • Enhance protection measures – like sea wall, protection of coastal wetland buffer • Need managed and planned retreat • Build more redundancy into the system • Require design and material changes and more corrosion free material • Improve drainage
More intense storm and storm surge	• Instantaneous damage to infrastructure • Inundation by sea during high wind • Obstruction due to fallen trees • Disruption and consequent impact on safety	• Need design standards to withstand storms • Adapt to high wind speed and heavy rain • Improve weather forecasting to predict storm and reduce damage • Emergency plan for evacuation routes in high risk areas

Source: Adapted from GIZ module on adaptation

Box 13.3 Case Studies: Climate Resilient Infrastructure

Globally, coastal cities have taken the lead to adopt climate resilient infrastructure. Hong Kong and Copenhagen are managing flooding during extreme heavy rainfall, which is important in low-lying delta cities with high water tables that are unable to drain or naturally manage rainfall.

Hong Kong has overhauled its drainage infrastructure after conducting detailed hydraulic studies of its different drainage basins. It has innovatively implemented the Happy Valley Underground Stormwater Storage Scheme—the first of three such schemes—comprising storage tanks with a capacity of 60,000 cum that are being constructed beneath several sports fields.

Copenhagen has decided to “fight flooding with flooding” by lowering its parks and raising the sidewalks of the streets connected to the parks. During extreme downpours, the parks will turn into temporary reservoirs while the streets will channelize water towards the city’s harbour.

Singapore adopts a similar approach to Hong Kong and Copenhagen in storm water and flood management. It has adopted “source-pathway-receptor” approach, using green roofs, rain gardens or retention ponds to slow down the flow of storm water discharged from buildings into the drainage system at the source. It also manages storm water discharge through measures such as widening and deepening of drains and canals, as well as construction of flood barriers. Singapore is taking measures to address future sea level rise, including raising Nicoll Drive next to Changi beach by 0.8m above its present level.

13.3.6 *Road Construction and Energy Conservation*

A parameter that has significant impact on fuel efficiency of vehicles is the tyre rolling resistance. This is influenced by stiffness, texture and smoothness of the road surface. This should be built into the road construction and maintenance guidelines.

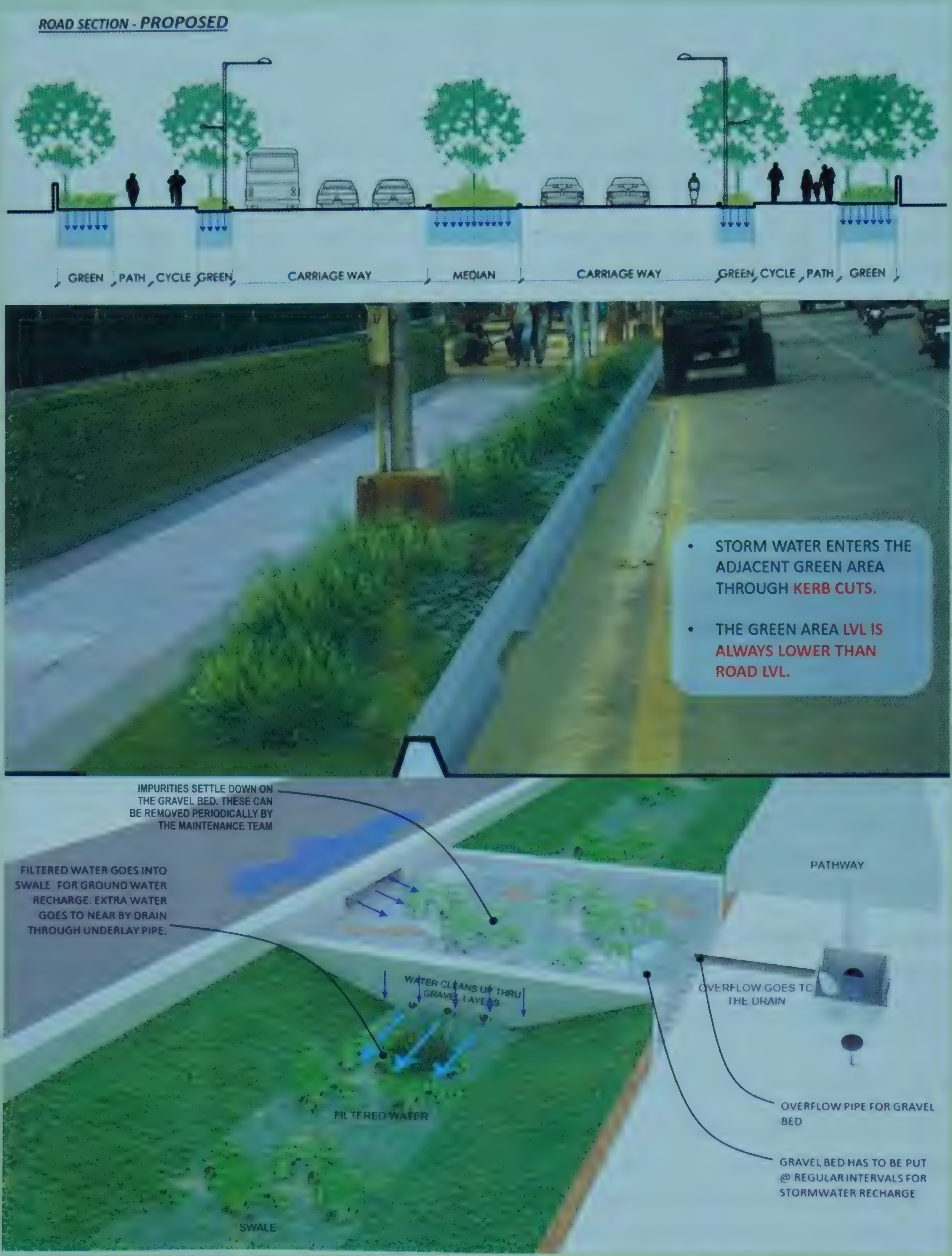
This area will require innovation in design, materials, asphalt, cement, lighting and signals. Sustainable practices will require utilising local sources to minimise the import of materials; stablilising additives to adapt local marginal materials while managing impacts on local environment and biodiversity. Material with low embodied energy and low cement content are needed.

13.3.7 *Leverage Road Construction and Design to improve Water Security*

Cities need a paradigm shift from the conventional approach of 100 per cent run off through storm water drains, to near zero run off by capturing the rain within the city to strengthen water security. This will have significant impact on road design as road networks are aligned with city’s drainage system. Road design and its aligned drainage systems have to tap road water runoff and ensure capture and treatment.

To enhance water holding capacity of the city, it is important to enhance water retention capacity of the road design. Roads can be designed to integrate natural storm water infiltration and absorption through bio-filtration beds, swales and detention ponds (see **Box 13.4**). On narrow roads, drains can be used to carry water to nearby large green areas for storage or recharge. Curb cuts can be used effectively. Road design can include effective filtration systems of gravel or vegetative filters. Bioswale can use bio retention media to improve water quality, reduce and moderate peak run off, and manage excess run off. Even, on-street parking can have pervious paving to capture water. Water sensitive road design can allow integration of biological processes for removal of pollutants, flow control, treatment in the Right of Way (RoW) itself. The drainage network itself can become efficient eco-mobility zones that can promote zero emissions mobility through walking and cycling. This will reduce transport related emissions.

Box 13.4 Water Sensitive Road Design


ROAD SECTION - PROPOSED
GREEN
PATH
CYCLE
GREEN
CARRIAGE WAY
MEDIAN
CARRIAGE WAY
GREEN
CYCLE
PATH
GREEN
IMPURITIES SETTLE DOWN ON THE GRAVEL BED. THESE CAN BE REMOVED PERIODICALLY BY THE MAINTENANCE TEAM
FILTERED WATER GOES INTO SWALE FOR GROUND WATER RECHARGE. EXTRA WATER GOES TO NEAR BY DRAIN THROUGH UNDERLAY PIPE.
PATHWAY
WATER CLEANS UP THRU GRAVEL LAYERS
OVERFLOW GOES TO THE DRAIN
FILTERED WATER
OVERFLOW PIPE FOR GRAVEL BED
GRAVEL BED HAS TO BE PUT @ REGULAR INTERVALS FOR STORMWATER RECHARGE
SWALE

- STORM WATER ENTERS THE ADJACENT GREEN AREA THROUGH KERB CUTS.
- THE GREEN AREA LVL IS ALWAYS LOWER THAN ROAD LVL.

Source: UTTIPEC/DDA

Prior to the road construction and design to improve water security, it is important that a storm water management plan is prepared. Like in many other local planning issues, GIS plays a crucial role in managing storm water as brought out in Chapter 8. Therefore, a GIS based mapping and data management is needed. This database could be used for aligning of road network and its infrastructure keeping in view, the terrain, natural features and water bodies to prevent damage of the ecosystem and retrofitting of roads in future. The checklist for creating a data inventory by Urban Local Bodies is given below:

- Surface Parking Lots
- Sidewalk
- Road Carriageway
- Building Footprint
- Impervious Surface
- Tree and Tree Canopy
- Forest Fragmentation
- Curve Number
- Roof Garden or Green Roof
- Storm Water Inlet and Outlet
- Watershed Boundary
- Stream
- Stream Bank
- Floodplains
- Drainage Network
- Water Distribution Network
- Wetland
- Natural Water Reservoir (Pond, Detention Basin)
- Management Practices (Trenches, Infiltration Galleries, Wet Pond, Storm Water Wetland, etc.)
- High Water Marks
- Riparian Buffer Status
- Orthophoto
- Digital Elevation Model
- Triangulated Irregular Networks
- Contours
- Land Use
- Public Property
- Soil

13.3.8 *Improve Water Efficiency during Road Construction*

Road construction itself consumes a lot of water that is not accounted for in conservation solutions. Countries like Australia have started to undertake water accounting to adopt water conservation methods in road construction (see **Box 13.5**). Road construction agencies are then encouraged to use water more efficiently and innovatively.

Box 13.5 Improved Water efficiency during Construction

The Australia Green Infrastructure Council (AGIC) rating scheme has been developed to encourage a greater level of water efficiency across a project's life cycle. This requires that measurement, monitoring and reporting of water use becomes the norm. This will establish the typical water usage footprint, against which other projects can be compared. The AGIC rating scheme minimises the volume of water used and encourages locally appropriate alternative water sources as substitutes for potable water. The tool has been created with a focus on additional water use, not on the use of storm (or waste) water or the embodied water in road construction materials.

13.3.9 *Use of Recycled Waste Material and Waste Management*

Construction and demolition cause enormous waste - about half of all materials used, that degrades the land and environment. It is estimated that as much as 530 million tonnes of construction and demolition waste is generated annually (CSE, 2016). These include demolished structures, renovations, as well as construction and repair of roads, flyovers, bridges, etc. In addition, enormous debris comes from disasters like earthquakes and floods. These are either thrown in city landfills or in open spaces, water bodies and flood plains. However, increasingly focus is shifting towards use of recycled waste material, and use of road bases that reuse previous pavement layers as a resource material to lower the demand for material from virgin quarries.

Waste management is required during construction and post construction to grading materials based on their toxic levels, reusability and durability etc.

In 2016, the Ministry of Environment and Forests and Climate Change (Government of India) issued a notification on Construction and Demolition (C&D) Waste Management Rules, which provides for reuse and recycle of C&D waste. This can substitute material mined from nature and prevent damage to water bodies, public spaces and green areas.

13.4 Monitoring and Evaluation

Monitoring and evaluation arrangements need to be put in place for a feedback on implementation of environment management plans and climate resilient strategies. Measurement, reporting, and verification are important steps in assessing the effectiveness of a climate change adaptation effort. Demonstrating that a mitigation action or strategies has reduced vulnerability and risks, and increased adaptive capacity helps to inform future planning and decisions. Capacity building and training workshops should be part of the action plan.

CHAPTER 14

LIGHTING

14.1 Background

Lighting is not only a functional requirement, which provides safety and security to pedestrians, non-motorised vehicle users and motorists, residents, but it also helps in making the city livable, safe and more conducive to social and economic activities. A well-lit city is always a reassuring place for its residents to stay and move around. Lighting can promote security in urban areas, increase the quality of life and reduce the harm related to darkness by extending the hours of illumination so that activities can take place. Globally, road lighting standards have been revised to address the growing complexity of traffic conditions-both volume and density, and addressing need of energy conservation and energy efficiency. There is need to have common standards of lighting on streets, based on which, agencies can execute projects within their scope of work. The lighting standards proposed for roads and streets in urban areas are to be in line with IS:1944. This chapter aims to set recommendation aligning with current international practices and at the same time conforming to the conditions laid down in IS:1944.

14.2 Definitions

The terms given here are taken from IS:1944.

- *Illuminance* — illuminance is the total luminous flux incident on a surface, per unit area. It is measured as lumen per square meter (Lux).
- *Overall Uniformity* (U_0) — it is the ratio of the minimum illuminance at a point to the average road surface illuminance. A good overall uniformity ensures that all spots on the road are sufficiently visible.
- *Transverse Uniformity* (U_T) — it is the ratio of the minimum illuminance at a point to the maximum road surface illuminance. A good transverse uniformity assist in the visibility of obstacles.
- *LRV* — Light Reflectance Value (LRV) is the total quantity of visible light reflected by a surface at all wavelengths and directions when illuminated by a light source.
- *Luminosity Contrast* — Also known as tonal contrast, is the most important element that assists persons with visual impairments to distinguish between two different surfaces. A minimum difference of 26 points in the LRV of colours of two architectural surfaces produces an adequate luminosity contrast that is perceivable by persons with visual impairments.
- *Lux* — Standard unit of illumination. It is used as a measure of perceived intensity of light.
- *Beam* — The portion of the light output of the luminaire contained by the solids angle subtended at the effective centre of the luminaire containing the maximum intensity but no intensity less than 90 percent of the maximum intensity.
- *Polar Curve* — Curve of light distribution using polar co-ordinate.
- *Throw* — The extent to which the light from the luminaire is distributed along a road.
- *Spread* — The amount of sideway spread of the light, across a road.

Table 14.1 Determination of Uniformity and Lux Level according to type of Roads

Road Classification	**Type of Carriageway**	**Width of Carriageway**	**Illuminance E_{avg}/E_{min}: E_{avg}/E_{main}: E_{max}**
Arterial and Sub arterial	Dual/Single Carriageway	> 10.5, 12, 14, 16, 18, 20, 30m	40/0.4/0.33
Sub arterials	Single Carriageway	>7 m up to 10 m	25/0.4/0.33
Collector and Local Streets	Single Carriageway	> 7 m up to 10 m	20/0.4/0.33
Slip/Service Road	Single Carriageway with Slow Speed traffic	m, 5m, 6m,	20/0.4/0.2
Pedestrian walk ways/ Cyclist Pathways	Single Carriageway, No motorized traffic	Width of Pathways 3m ~	15/0.4/0.2
Pedestrian Crossings	Pedestrian Cross Over points	Clear demarcated Zebra crossing	30 lux
Bus bays	Bus Alignment points	Demarcated Bus Points Bus Bay on other roads	40 lux 30 lux
Intersections and Rotaries 30-50m dia			50 lux/0.4
Intersections and Rotaries			30 lux/0.4

14.3 Selection of Lighting Level

The recommendations for lighting are divided into different groups, which are selected according to the function of the road, traffic density and traffic complexity.

Lighting using Street light poles with LED Street Lights:

The average illuminance on the road surface ($E_{Avg.}$), the overall uniformity of illuminance ($E_{min}/E_{avg.}$), the transverse uniformity of the illuminance (E_{min}/E_{max}) are to be calculated and measured. The lighting levels required for various categories of roads are given in **Table 14.1**.

14.3.1 *Lighting requirements for different Categories of Roads and Streets*

Road lighting systems uses lamps, luminaires and control gear to achieve certain specified lighting conditions. It is a good practice, to specify requirement of both products and lighting parameters . Lighting Parameter are given below:

- Lighting Level (Illuminance in lux and luminance in cd/m^2); and
- Uniformity.

In this type of lighting mostly decorative type fixture is used. In this type of system luminaire housing is very important. Ballast specification is really important. There are many luminaire selection criteria which are given below:

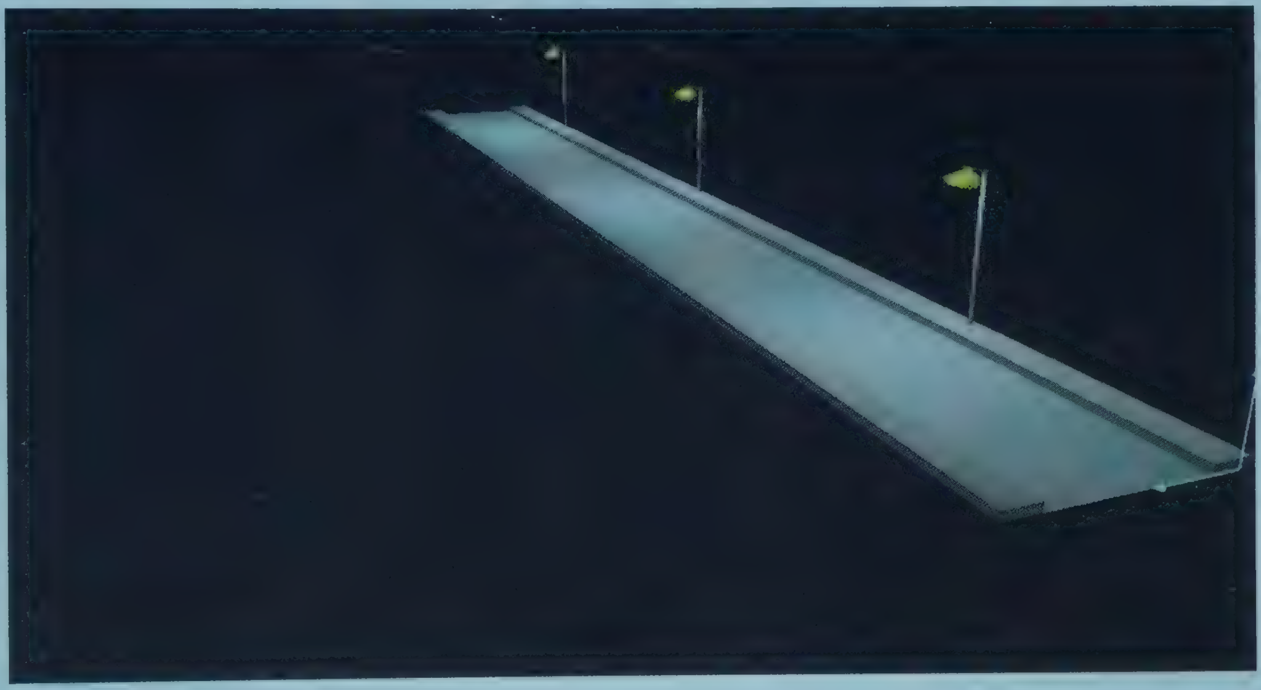
a) Mechanical;

b) Electrical;

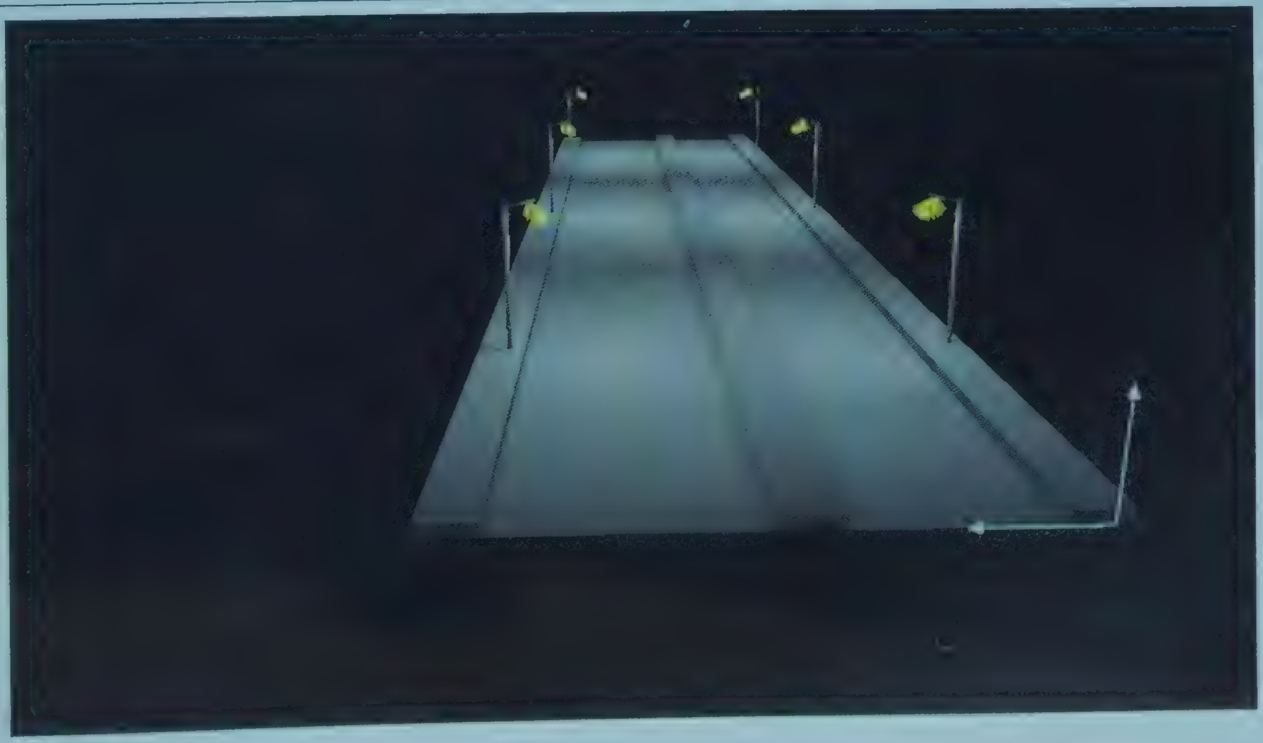
c) Required lamp types;
d) Ambient operation temperature;
e) Required IP rating;
f) Air resistance, with/without bowl, with/without gear unit;
g) Component exchangeability, accessories;
h) Mounting functionality;
i) Material requirement.

In this type of luminaire arrangement, street lights are spread over long distances and it is difficult to operate these individually. One of the important links is the use of underground cables or special overhead wires to form a group control point. The different types technologies that can be used are control switch, time switch, photoelectric switch, computerized switch, step diming and tele-management.

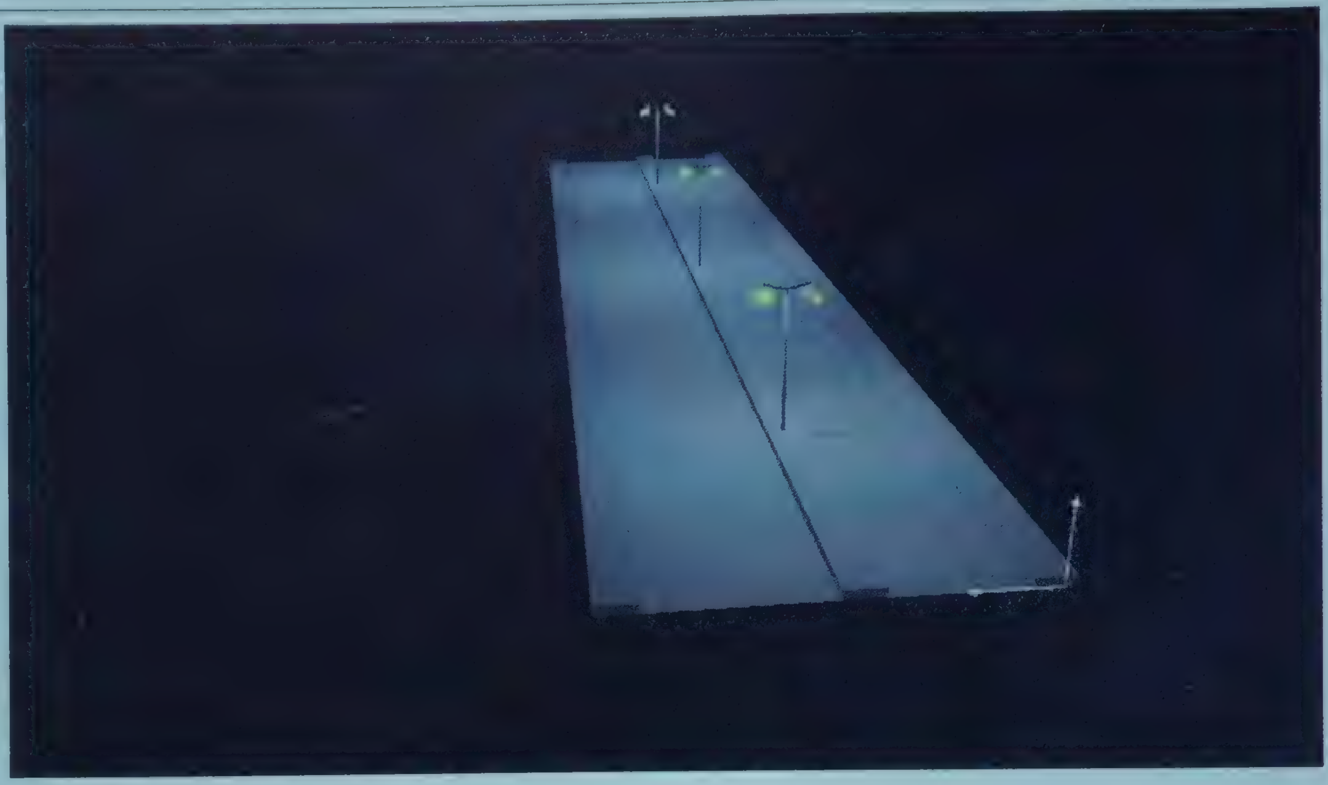
The different type of arrangement that can be seen here are:



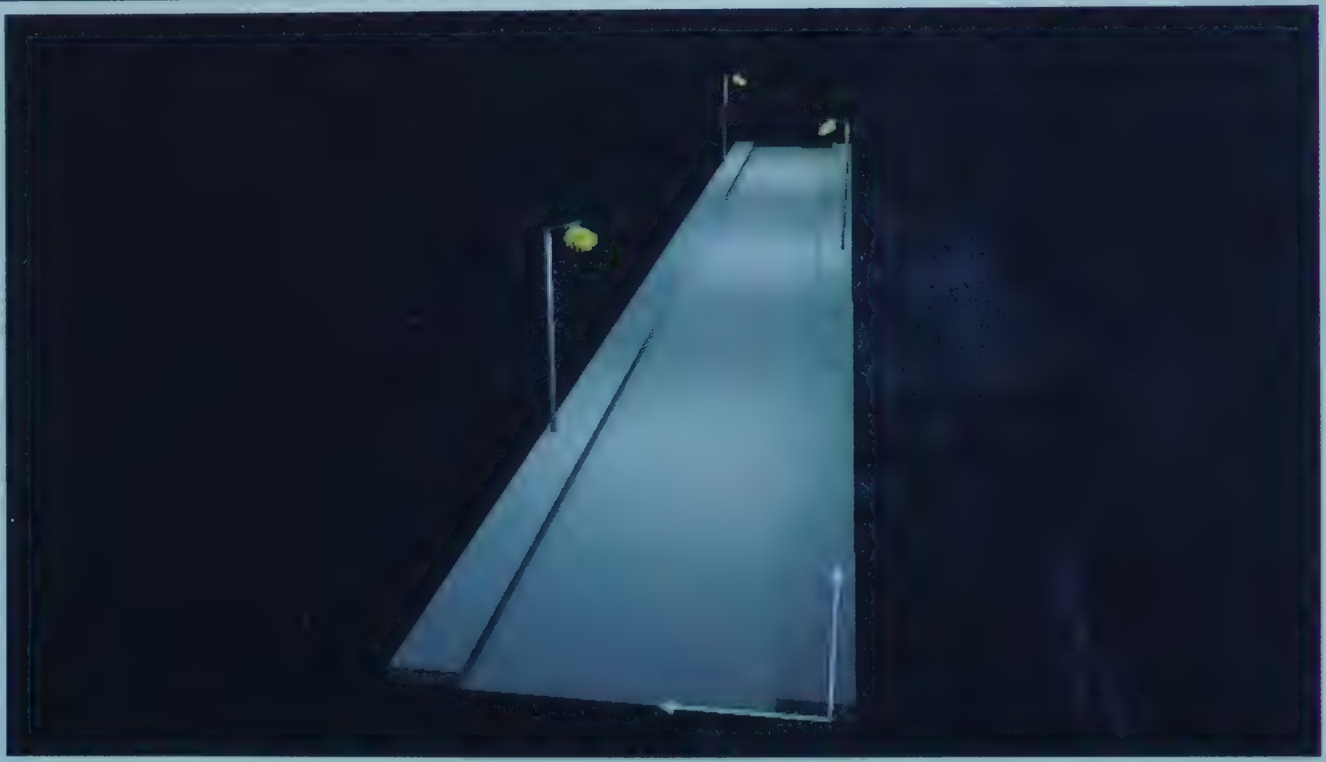
Single Sided Arrangement



Opposite Side Arrangement



Twin Central Arrangement



Staggered Arrangement

Fig. 14.1 Types of Lighting Arrangements

14.3.2 *Luminaries Selection*

For Designing purpose Computer simulation software acceptable to the Lighting Division shall be used for the calculation of road lighting luminance, illuminance, uniformity and glare. The software programs shall be based on BS EN 13201-3 in which the driving convention is identical to our local environment.

TERMS RELATED TO LIGHTING INSTALLATION

- **Lighting Installation -**The whole of the equipment provided for lighting the highway comprising the lamps, luminaires, means of support and electrical and other auxiliaries.

- **Lighting System -** An array of luminaires having a characteristic light distribution, sited in a manner concordant with this distribution. (Lighting systems are commonly designated by the name of the characteristic light distribution, for example, cut-off, semi-cut-off, etc).
- **Luminaire -** A housing for one or more lamps, comprising a body and any refractor, reflector, diffuser or enclosure associated with the lamp(s).
- **Outreach -** The distance measured horizontally between the centre of the column or wall face and the centre of a luminaire.
- **Overhang -** The distance measured horizontally between the centre of a luminaire mounted on a bracket and the adjacent edge of the carriageway.
- **Mounting Height -** The vertical distance between the centre of the luminaire and the surface of the carriageway.
- **Spacing -** The distance, measured along the centre line of the carriageway, between successive luminaires in an installation.
- **Span -** That part of the highway lying between successive binaries in an installation
- **Width of Carriageway -** The distance between kerb lines measured straight angles to the length of the carriageway.

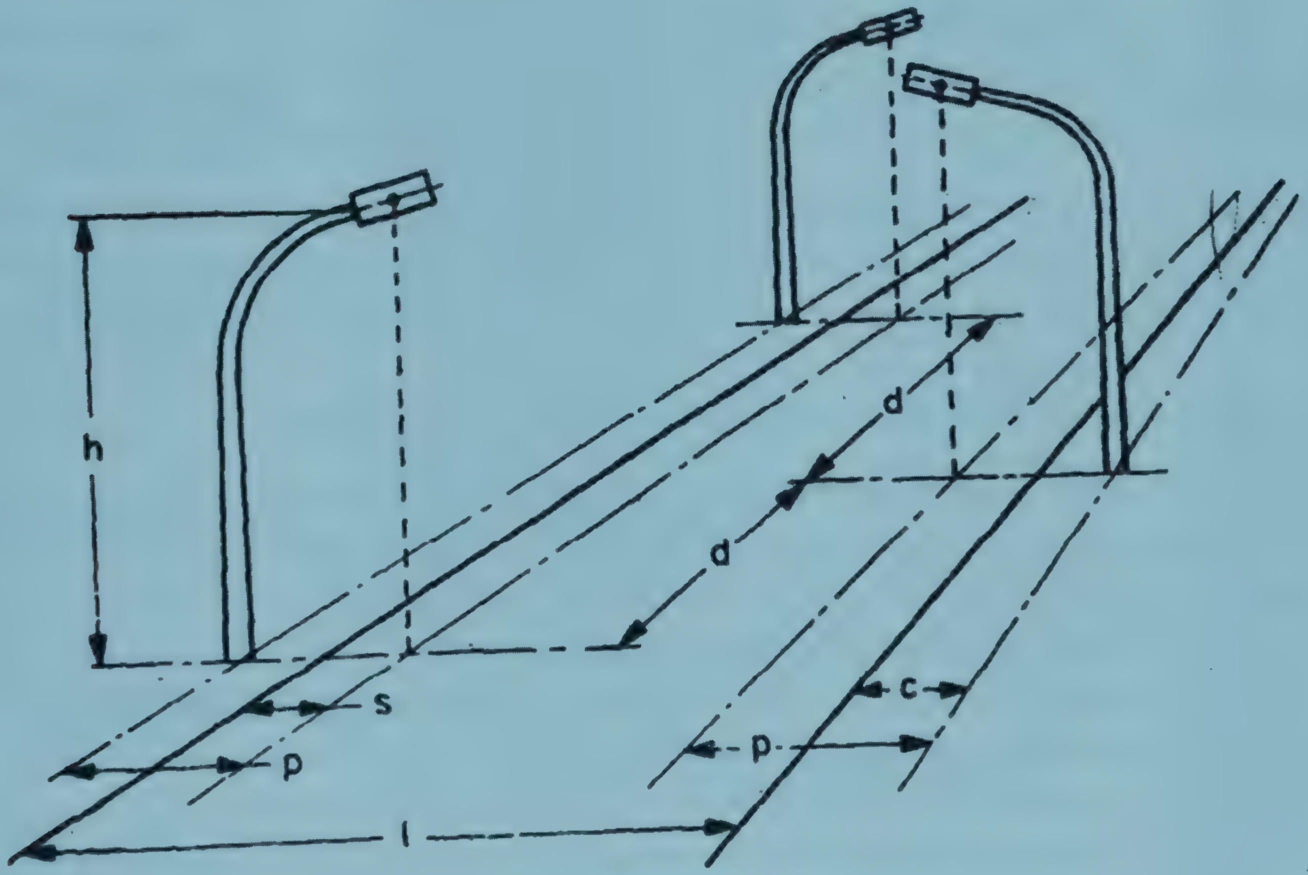


Fig. 14.2 Elements of Lighting Installation

h=mounting height; d=spacimg; l=width of the road; p=outreach; s=overhang; c=clearance

14.3.3 *Classification of Lighting*

Classification is one of lighting and not of roads, but is linked with traffic density. It is left to the local engineer to decide upon the category of the lighting for the given road. Lighting for streets is classified into the following groups:

Group A - For main roads. This is sub-divided into two categories:

Group A1 - For very important routes with rapid and dense traffic where the only considerations are the safety and speed of the traffic and the comfort of the drivers.

Group A2 - For other main roads with considerable mixed traffic like main city streets, arterial roads and thoroughfares.

Group B - For secondary roads which do not require lighting up to Group A standard. This is also divided into two categories:

Group B1 - For secondary roads with considerable traffic, such as principal local traffic routes, shopping streets, etc.

Group B2 - For secondary roads with light traffic.

Group C - Lighting for residential and unclassified roads not included in the previous groups.

Group D - Lighting for bridges and flyovers.

Group E - Lighting for town and city centres.

Group F - Lighting for roads with special requirements, such as roads near airfields, railways and docks

Maintenance factor, which is the ratio of average illumination on the working area, given by an installation with decreased effectiveness due to dust, pollution, line voltage drop, ageing of lamps, product tolerance etc. to that of a new installation shall be considered as 0.75.

While deciding about the illumination plan, consideration shall be given to energy efficiency, environmental pollution, aesthetic and economical aspects. The selection of lighting system and the layout should add to the overall aesthetics of the road section on which lighting is being done.

14.4 Lighting using High Mast for Junction and Toll Plaza

The same quality of lighting as recommended in **Table 14.1** above, may be used to provide lighting on individual road in the junction or the roads which are very wide. Recommended values for uniformity ratio are $E_{min}/E_{avg.} = 0.40$ and $E_{min}/E_{max} = 0.25$ High Mast Lighting: Normal low light poles are not able to give the required lighting conditions. It is, therefore, necessary to install high mast. A height of 30m for the mast is considered suitable to have uniform spread of desired level of illumination in the Toll Plaza area for safe movement of vehicles. Highway Lighting: A minimum requirement of illumination on the road surface of 40 Lux shall be ensured. Lighting in minimum 500m length on either side approaches of toll plaza shall be provided to enhance the safety at night on the Project Highway and to make the drivers conscious of their approaching the toll gate. These shall be provided on the mild steel welded tubular pole of 10m height from road surface and with 2m overhang. Sodium Vapour lamp of 200-250 watts should be provided for these poles on both sides at 50m staggered spacing. There should be provision for flashing signals for foggy weather conditions.

Selection of High Mast

India is a vast country with diverse climatic conditions. Wind speed at vaious locations change as per conditions. The high mast that should be installed must bear basic wind speed of the location and head loads.

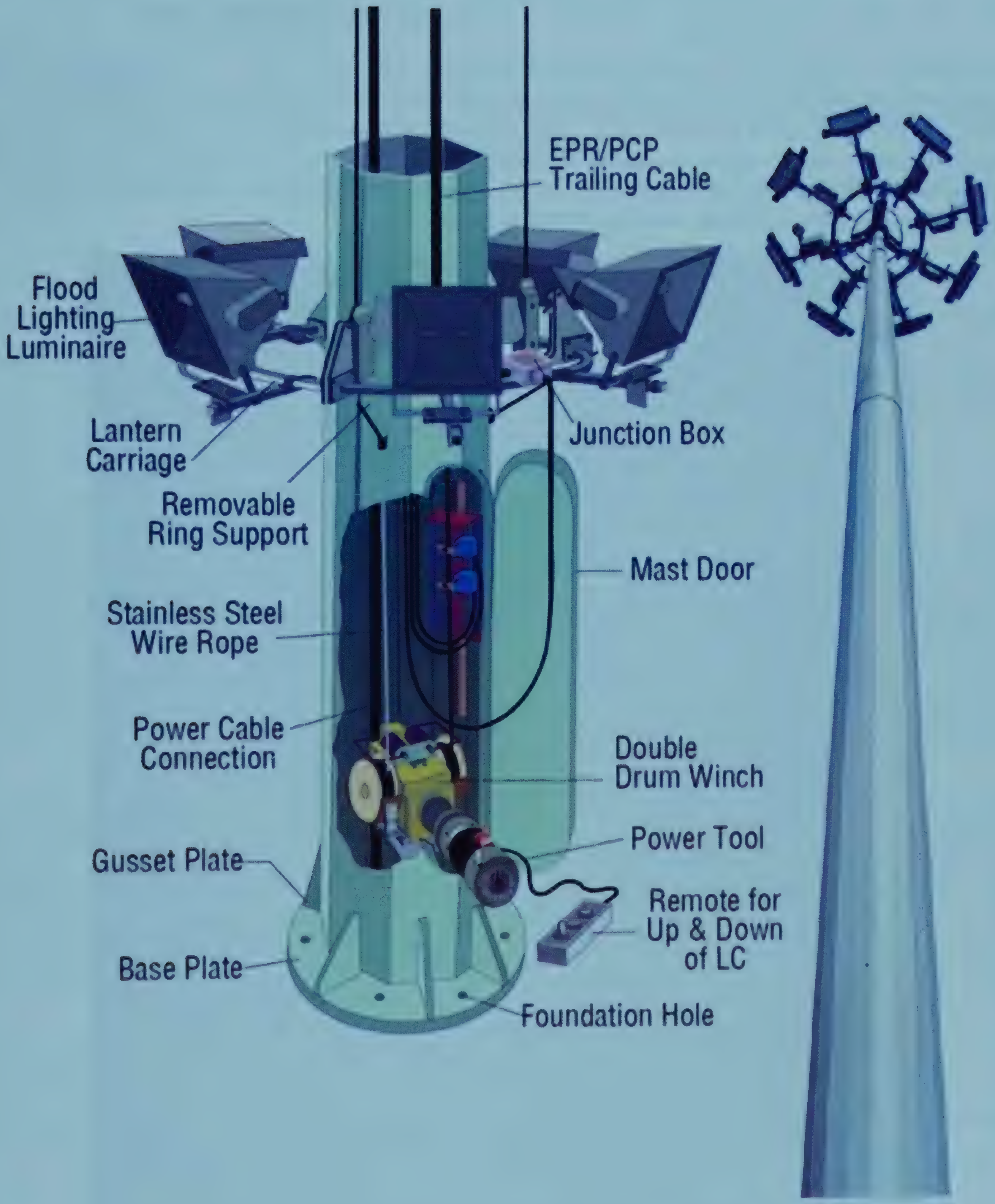

EPR/PCP Trailing Cable
Flood Lighting Luminaire
Lantern Carriage
Removable Ring Support
Junction Box
Mast Door
Stainless Steel Wire Rope
Power Cable Connection
Double Drum Winch
Power Tool
Gusset Plate
Remote for Up & Down of LC
Base Plate
Foundation Hole

Fig. 14.3 Typical Base Compartment of High Mast

High Mast lighting as a concept in area lighting is being preferred over conventional lighting especially where large areas are to be illuminated without the need for numerous lighting columns. High Mast lighting is ideal for industrial and commercial areas, docks, airports, stations, car parks and hazardous areas.

The length of the high mast that are used in the industries are of 12.5m, 16m, 20m, 25m and 30m. The length of the high mast should be chosen according to the application.

The sectional thickness of the high mast should be minimum 3mm. The dynamic loading, wind speed should be 180km/hr with a double drum type. The stainless steel grade should be (American Iron and Steel Institute) AISI 316. The stainless steel wire rope should be minimum 6mm in diameter. The breaking capacity of the high mast should be minimum 2350 Kg. The high mast lantern carriage can be symmetrical or asymmetrical, it depends on the type of usage. A integral motor should be there with the high mast.

Photo 14.3 Luminaries Selection (Flood Light/Street Light)

In outdoor scenarios, different type of lighting conditions is needed. **Table 14.2** shows parameters on Luminaire selection, it should be followed while selecting the luminaire for outdoor application.

Table 14.2 Parameter on Luminaire Classification

Sr. No.	Parameter	Requirement
1	Housing	High Pressure Die Cast Aluminium
2	Luminaire cover/glass	Heat resistant toughened clear glass/UV stabilised Polycarbonate
3	Luminaire mounting arrangement	Suitable for Ceiling/Surface/Wall mounted. Cradle arrangement should be 360° rotational for better installation. Vibration dapmper bushing to be provided to withstand in high traffic movement.
4	Hardware's/Fasteners	Allen Key type Stainless Steel screws to be provided to protect from theft.
5	Internal Wiring	Fire retardant low smoke zero halogen (FRLS- ZH)
6	Ingress Protection (IP)	IP 66
7	Mechanical Impact (IK)	IK 08
8	System Efficacy (lumen/watt)	≥ 150 Lm/W
9	Optical Assembly	High Power Discrete LED's with individual Lens designed to optimize application efficiency
10	Lens/Optics	Lens should be of Material resistant to de- gradation during service, due to atmospheric components to avoid adverse impact on light output.
11	LED Packages	High power single chip ceramic base LED package.
		Wattage of LED Package should be 1W minimum to 3W maximum.
12	Operating current of LED (design)	< 70% of rated maximum forward current, limited to a minimum of 350 mA and maximum of 1000 mA.
13	LED Efficacy	>180 Lm/W (at operating current design & Tj
		=85°C)
14	LED Surface Temperature (Ts)	The Solder point Temperature shall be < 85 °C at 30 °C Ambient Temperature
15	Colour Rendering Index (CRI)	≥70
16	Colour Temperature (Deg. Kelvin)	5700K ANSI BIN
17	Working Life for LED (@L70) (no of Hours)	Minimum 50,000 Burning Hours as per LM-80 Report
18	Power Factor	≥0.95
19	Operating Voltage range (Volts)	120 - 270 VAC
20	Input Frequency (Hz)	50
21	Total Harmonic Distortion (%)	<10%
22	Surge Protection (kV) external to Driver	5KV

Sr. No.	Parameter	Requirement
23	Humidity (% min & max - Relative humidity)	10% to 90% RH
24	Operating Temperature Range	-5 ° to 55 °C
25	Driver Type	Constant current 2 stage drivers for above 60W, Driver should be potted with onboard surge withstand capacity > 4KV
26	Driver Protection	Output Short Circuit, Output Open Circuit, Input over voltage
27	Input voltage range	120Vac - 270Vac
28	Input over voltage cut-off	> 300Vac
29	Low Input voltage withstand	48Hrs at 100Vac
30	Phase-Phase input (440Vac) withstand	for 8Hrs
31	LED ripple current	< 30% (Ipk/Idc) for < 60W
		< 10% (Ipk/Idc) for > 60W
32	Electrical Efficiency	> 85%
33	Driver Compliance	1. IS 15885 (Part 2/Sec 13) as per BIS Certificate
		2. The Driver should be ROHS compliant.
34	Driver Life class (Br. Hrs.)	>15000 Burning Hours

14.5 Other Important Factors

A few other important factors to be considered are:

- Choice of luminaires
- Siting of luminaires
- Mounting Height of luminaires
- Spacing of luminaires
- Overhang of luminaires

14.6 Aesthetics and Durability

Aesthetics and durability should be given due consideration.

For long term corrosion protection, heavy duty polymeric coating should be selected with following criteria:

- Environment friendly, solvent free epoxy, low Volatile Organic Compound
- "Direct to Metal" as well as compatible with Duplex system (on Galvanized surface)
- Suitable for both new structures and previously coated structures
- Suitable for urban and coastal environment
- Compatible with Aliphatic Polyurethane top coats as well as Graphical films

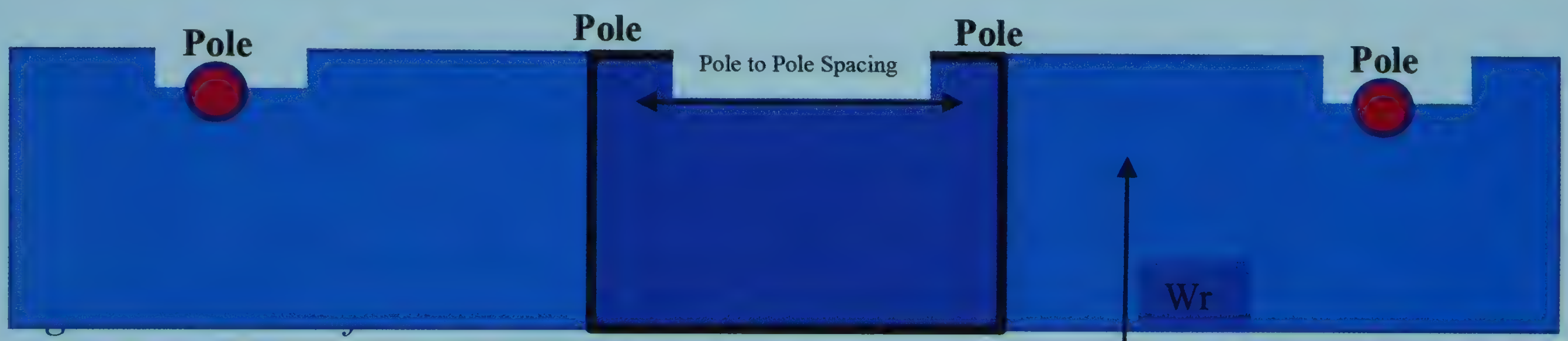
Table 14.3 gives the technical specifications for Polymeric Coating.

Table 14.3 Technical Specifications for Polymeric Coating

Performance Parameters	Test Reference Standards	Criteria
Volume Solids		100 %
Salt Spray Resistance	ASTM B 117	5000 Hrs
Humidity Resistance	BS 3900	5000 Hrs.
Pull Off Adhesion	ASTM B 117	>20 MPa [on grit blasted surface]
Water Vapor Permeability	ASTM D 1653	≤2 gm.mm/m²/24 hrs
Cross Section Porosity	NACE RP 0394	Rating 1
Abrasion Resistance	ASTM D 4060	<50 mg [1000 cycles,1 Kg Load, CS 17 Wheel]

14.7 Calculation of Performance

Field of Calculation for illuminance:



Position of Calculation Points as per BS EN 13201-3:2003:

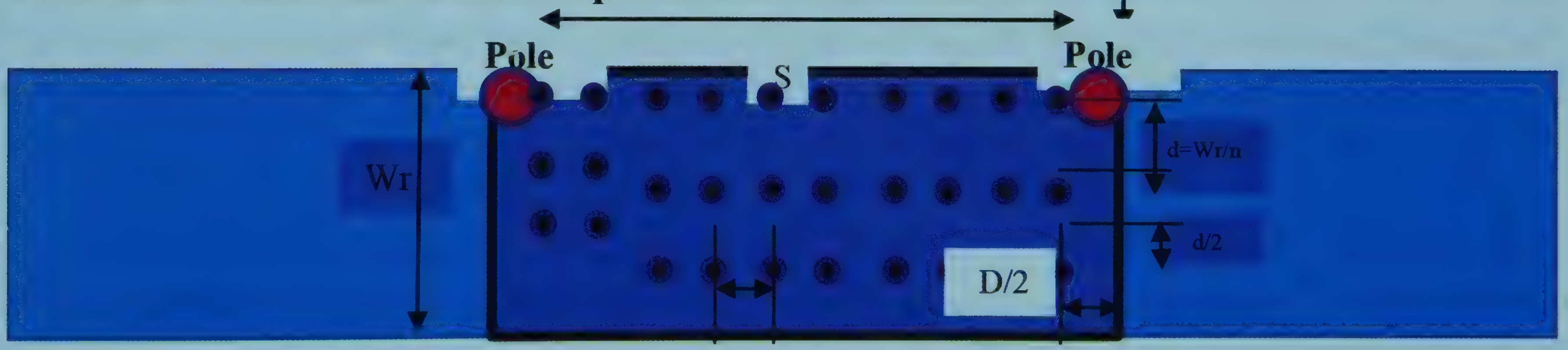


Fig. 14.4 Calculation Points on Relevant Area

The spacing of the points in the longitudinal and transverse directions shall be determined as follows:

a) In the longitudinal direction

$D = S/N$,

Where:

D is the spacing between points in the longitudinal direction, in metres

S is the spacing between luminaires in the same row, in metres

N is the number of calculation points in the longitudinal direction with the following values:

For $S \leq 30$ m, $N = 10$;

For $S > 30$ m, the smallest integer giving $D \leq 3$ m. The first transverse row of Calculation Points is spaced at a distance D/2 beyond the first luminaire.

b) In the transverse direction

The spacing (d) in the transverse direction is determined from the equation:

$d = Wr/n$:

Where:

d is the spacing between points in the transverse direction, in metres

Wr is the width of relevant area

n is the number of points in the transverse direction with a value greater or equal to 3 and is the smallest integer giving $d \leq 1.5$m.

The outermost calculation points are spaced d/2 from the edges of the carriageway.

Recommendation on Selection of the arrangement of the poles:

Selection of the Arrangement W= Width of the Road and H= Height of the pole

Table 14.4 Selection of the arrangements of the Poles

$W/H \leq 1$	Single Sided Arrangement
$1 < W/H \leq 1.5$	Staggered Arrangement
$W/H > 1.5$	Double Sided Arrangement
$W < H$	Axial Arrangement

The type of luminaire arrangements can be selected on the basis of width of the road and height of the pole. **Table 14.4** shows relation between the luminaire arrangement with W/H ratio, where W- Width of the road, H=Height of the pole.

14.8 Special Provisions for Lighting for Pedestrians

Lighting needs of pedestrians are different from those of vehicular traffic and therefore need to be designed and integrated within the overall lighting strategy for the street. This would aid the safety of pedestrians on pavements after dark. Main principles are given in **Table 14.5.**

Table 14.5 Main Principles of Lighting for Pedestrians

Mobility	Optimal lighting for pedestrians to provide safety and security. Light poles must be clear of the pedestrian walking zone.
Safety/Comfort	Provide optimal lighting for pedestrians. Pedestrian lights should be placed lower and focusing on footpath.
Ecology	Provide full cut-off lighting fixtures to prevent spillage of light and wastage of energy, and also prevent night sky light pollution.

14.9 Key Design Guidelines

i) Height of Light Pole and Luminaire Type are a function of Street Width:

- High Mast Lighting (30m tall) – are inefficient as too much light is dispersed into the night sky (causing light pollution) and not much light reaches the ground level.
- Mid-Mast Lighting (10-12m tall) – are appropriate for most Arterial and Sub-Arterial Streets. For Wide Streets with high pedestrian/commercial activity, Mid-Mast lighting may be combined with Pedestrian Scale lighting to create additional security and comfort.
- Low-Mast or Pedestrian Lighting (3-5m tall) – illuminate pedestrian-only walkways and provide supplemental light for the sidewalk.

ii) Different types of streets require different types of lighting. Approx. 30 lux level is suitable for non-shopping areas and 20-25 lux-level for shopping areas.

iii) Key aspects of planning for optimum street lighting are:

- Evaluation of adjacent land uses.
- Evaluation of activities (especially night-time activities) on the street.
- Street Lighting must not pollute the environment, i.e. no night sky light pollution.
- Energy efficient fixtures should be utilized that give good value for money, i.e are durable, rugged and inexpensive.
- Concentrated lighting is required at all road intersections and junctions, as well as bus stops, Metro exits, near crosswalks, street furniture, public amenities and important signage.
- While placing street lights, ensure adequate gaps and spacing from the tree canopies to ensure that performance of lighting is not compromised.

iv) Key aspects of design are:

- Height of light pole is a function of street width.
- Narrower the street width, lower should be the lamp height.
- Expert advice should be taken from an electrical engineer for design calculations including for pole height, type of luminaries, etc. for achieving appropriate lighting levels at all parts of the street.
- Tree planting plan and lighting plans must be prepared in conjunction – so that tree canopies do not obstruct lighting for road users.
- The light-pole placement should not interfere with the clearance of the main pedestrian walking zone i.e. footpath. Light pole may preferably be located within the tree-planting zone. (See **Figs. 14.5** and **14.6**)

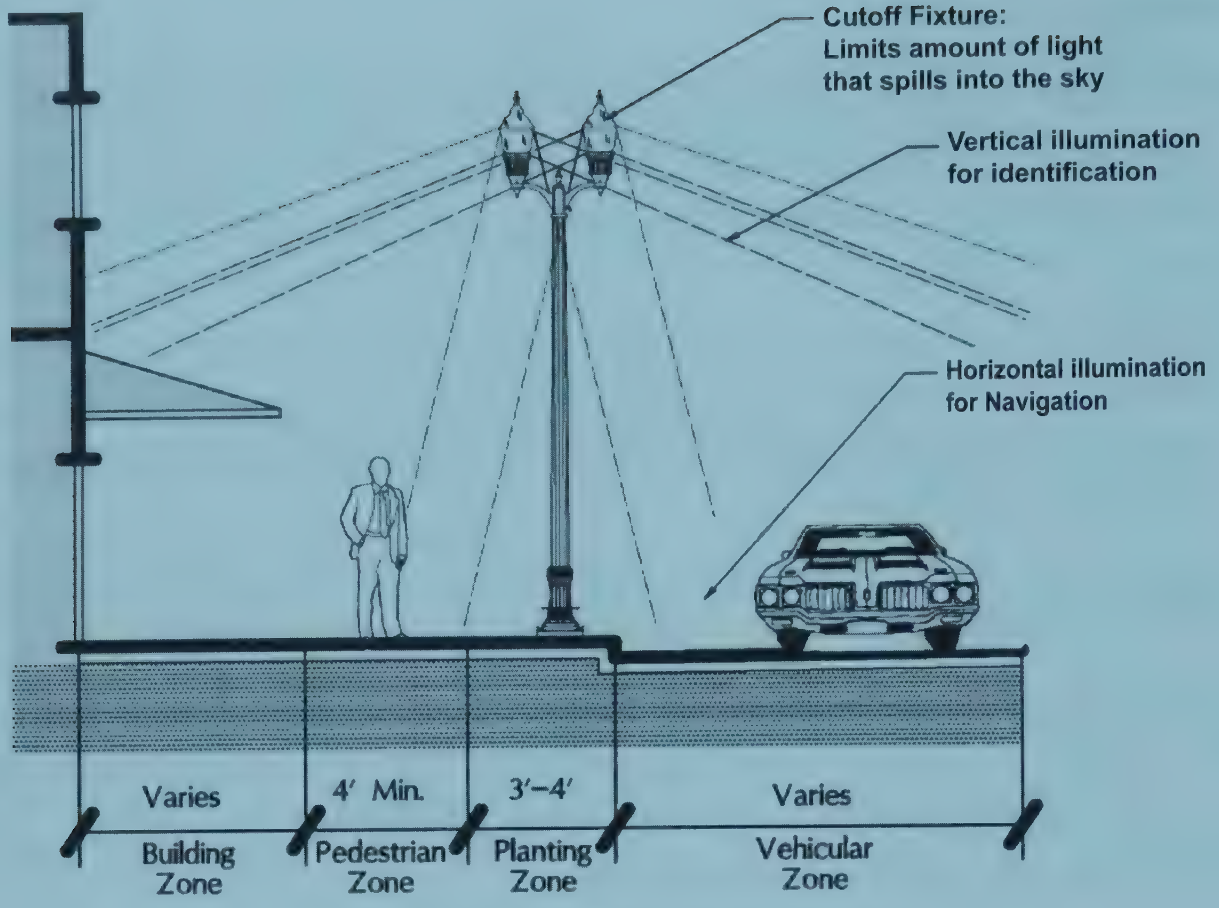

Cutoff Fixture:
Limits amount of light
that spills into the sky
Vertical illumination
for identification
Horizontal illumination
for Navigation
Varies
4′ Min.
3′–4′
Varies
Building
Zone
Pedestrian
Zone
Planting
Zone
Vehicular
Zone

Fig. 14.5 Light Pole Placement

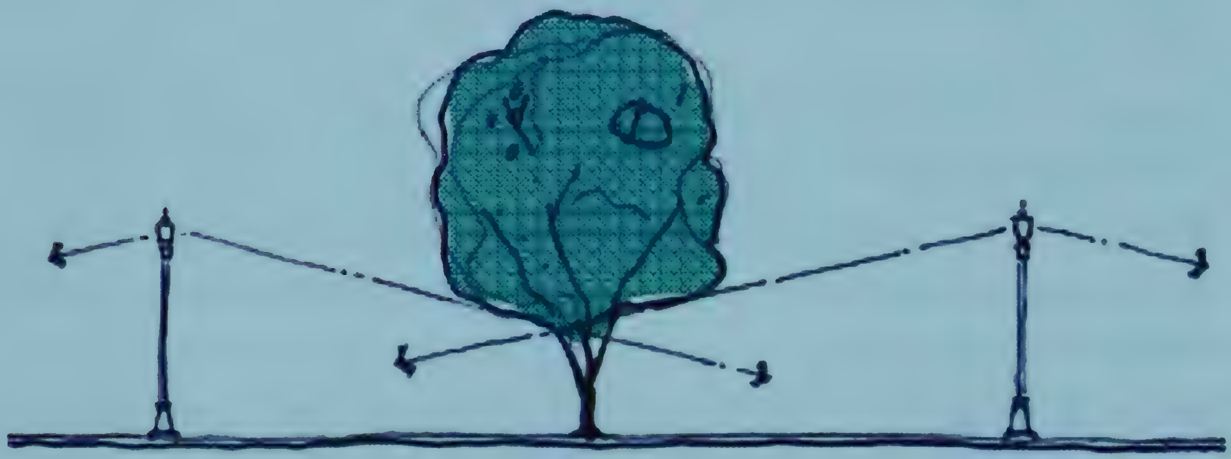


Fig. 14.6 Light cut-off with respect to Trees

14.10 Fixtures Light Distribution

The Luminaire has a double role of protecting the light source from the weather and redistributing its luminous flux. As the vertical light angle increases than disability and discomfort glare also increase. To distinguish the glare effects on the driver created by the light source, IS:1944 has defined the vertical control of light distribution.

Four fundamental forms of light distribution are considered according to the degree of glare which is acceptable:

14.10.1 *Full Cut-Off*

A luminaire whose light distribution is characterized by a rapid reduction of luminous intensity in the region between about 80° and the horizontal. The intensity at the horizontal should not exceed 10 cd per 1000 lm of flux from the light sources and the intensity at 80° is of the order of 30 cd per 1000 lm. The direction of the maximum intensity may vary but should be below 65°.

14.10.2 *Cut-Off*

A Luminaire whose light distribution is less than 2.5% of the light can leave the fixture above 90° and 10% or less emitted at the 80° angle of nadir.

14.10.3 *Semi Cut-Off*

A luminaire whose light distribution is characterized by a less severe reduction in the intensity in the region 80° to 90°. The intensity at the horizontal should not exceed 50 cd per 1000 lm of flux from the light sources and the intensity at 80° is of the order of 100 cd per 1000 lm. The direction of the maximum intensity may vary but should be below 75°.

14.10.4 *Non Cut-Off*

A Luminaire whose luminous intensity in directions making an angle equal to or greater than 80" from the downward vertical is not reduced materially and the intensity of which at the horizontal may exceed the values specified for the semi-cut-off distribution, but should not nevertheless exceed 100% cd. Non-cut-off luminaires are permissible only when a certain amount of glare may be accepted and when the luminaires are of large size and of reduced brightness. In certain cases they have some advantages in increasing the illumination on facades.

14.10.5 *Key Design Guidelines*

- Full cut off fixtures which focus light downwards and allow no light towards the night sky, and also do not cause glare – are required for all public streets.
- Lighting shall be directed downward at all times (up-lighting would be prohibited)
- Over-lighting an outdoor area at night is not the best solution for security or safety. Instead, exterior lighting that provides low contrast on critical areas improves visual acuity and safety.
- The light color of lamps also affects safety: illuminating objects with products that have high Color Rendering Indices (CRI) improves visual recognition at night.
- See **Fig. 14.7** for light fixtures
- All exterior lighting shall have shielding as per **Table 14.6**.

Table 14.6 Types of Lighting Fixtures

Fixture Lamp Type	Residential Area Shielded	Commercial/Industrial Area Shielded
Low Pressure sodium	Fully	Fully
High Pressure sodium	Prohibited except fully shielded on streets	Fully
Metal Halide	Prohibited	Fully
Fluorescent	Fully	Fully
Quarts	Prohibited	Fully
Incandescent >60 watts	Fully	Fully

Fixture Lamp Type	Residential Area Shielded	Commercial/Industrial Area Shielded
Incandescent 60 watts or less	No requirement	No requirement
Glass Tubes filled with Neon, Argon, or Krypton	No requirement	No requirement
Mercury Vapor	Prohibited	Fully
Halogen	Prohibited	Fully
Searchlights for advertising purposes	Prohibited	Prohibited

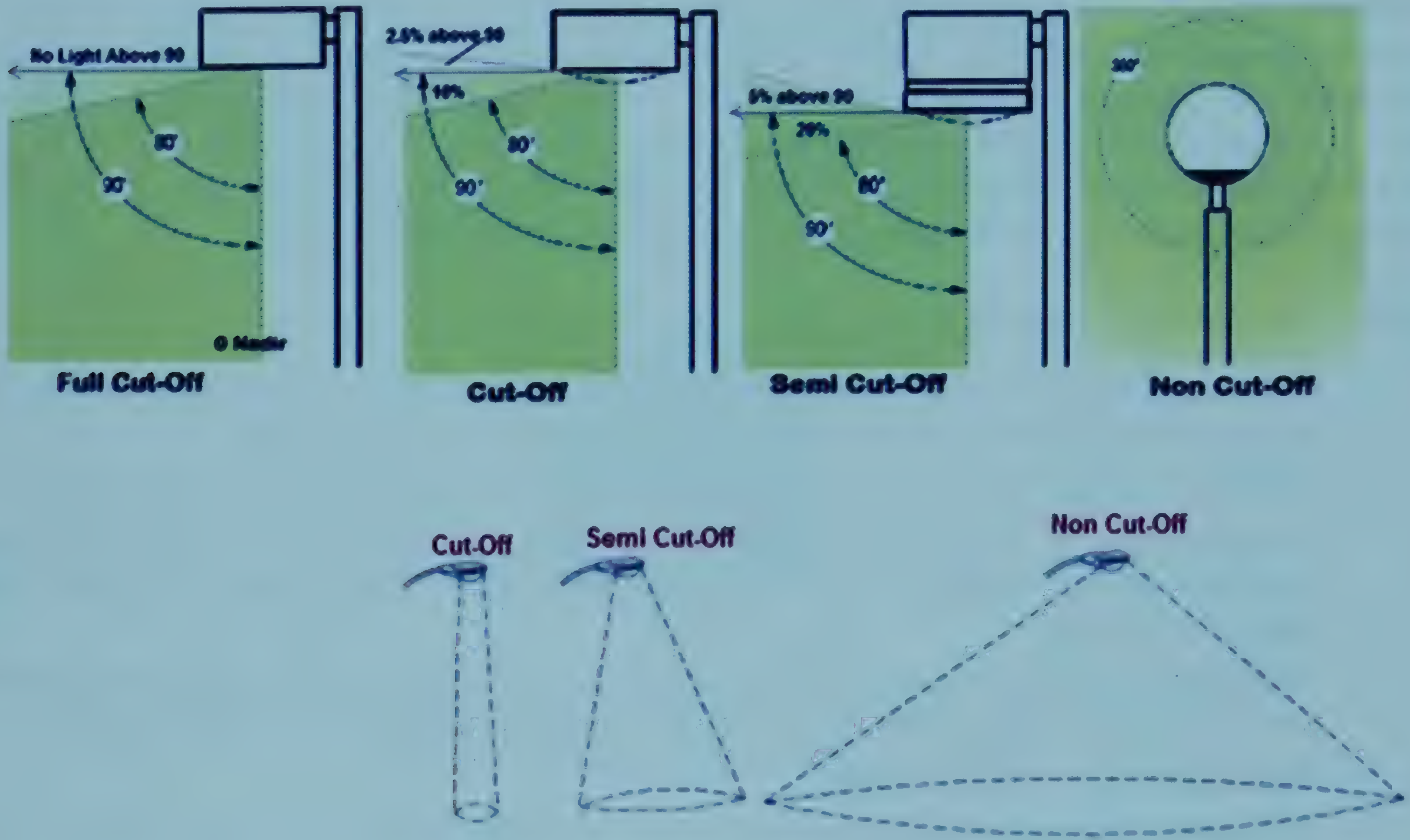


Fig. 14.7 Light Fixtures

14.11 Energy Efficient Lighting

In 2012, the Bureau of Energy Efficiency (BEE) and Bureau of Indian Standards (BIS) introduced 10 comprehensive performance, safety, and quality standards for the LED lighting (**Table 14.7**) as part of the Government of India (GOI) initiative to introduce and promote energy-efficient street lighting in the country and to introduce the concept of sustainability in the ULBs, although these standards are not specific to the street lighting standards.

In addition, BIS has also issued a National Building Code 2010, as a guidebook on comprehensive source for lighting projects for various applications in the country. The guidebook has specific sections on Road Lighting and Energy-Efficient Lighting Systems. The ULBs and project design consultant may refer to the code, for reference with respect to the project design of street or public lighting system.

Table 14.7 BIS LED Lighting Standard (As per BIS 2012)

S. No.	Standards Title	Indian Standards	International Standards
1	Terms and Definition	IS 16101:2012	IEC 62504 TS
2	Self-ballasted LED lamps for general lighting services Part 1, Safety Requirements	IS 16102 (Part 1):2012	IEC 62560
3	Self-ballasted LED lamps for general lighting services Part 2, Performance Requirements	IS 16102 (Part 2):2012	IEC 62612
4	LED modules for general lighting Safety Specifications	IS 16103(Part 1)	IEC 62031
5	LED modules for general lighting Part 2, Performance Requirements	IS 16103 (Part 2)	IEC 62717
6	DC- or AC-supplied electronic control gear for LED modules—Performance Requirements	IS 16104:2012	IEC 62384
7	Method of measurement of lumen maintenance of solid state light (LED) Sources	IS 16105:2012 IS 16106:2012	LM 80
8	Electrical and Photometric Measurements of Solid-State Lighting Products		LM 79
9	LED luminaires for general lighting	IS 16107(Part 1)	34D/950/NP
10	LED luminaires for general lighting Part 2, Performance requirements	IS 16107(Part 2)	34D/977/DC
11	Photo biological Safety of LED and LED System	IS 16108:2012	IEC 62471

14.12 Types of Lamp Technologies

Various types of lamp technologies are prevalent in the market. These technologies greatly vary in their luminous efficacy, colour rendering properties, and lamp life. A brief description of types of lamp technologies currently available is provided in **Table 14.8**. Street lighting commonly uses high-intensity discharge lamps, often HPS (High Pressure Sodium) lamps.

Table 14.8 Types of Lamp Technologies (Source: USAID 2010)

Type of Lamp	Luminous Efficacy (lm/W)	Color Reducing Properties	Lamp Life	Remarks
High Pressure Mercury Vapour	35-36	Fair	10000-15000	High energy use, poor lamp life
Metal Halide (MH)	70-130	Excellent	8000-12000	High luminous efficacy, poor lamp life

Type of Lamp	Luminous Efficacy (lm/W)	Color Reducing Properties	Lamp Life	Remarks
High Pressure Sodium Vapour	50-150	Fair	15000-24000	Energy-Efficient, poor color rendering
Low Pressure Sodium Vapour (LPSV)	100-190	Very Poor	18000-24000	Energy-Efficient, very poor color rendering
Low Pressure Mercury Fluorescent Tubular Lamp (T12 & T8)	30-90	Good	5000-10000	Poor lamp life, medium energy use, only
EE Fluorescent Tubular Lamp (T5)	100-120	Very Good	15000-20000	EE, long lamp life, only available in low
Light Emitting Diode (LED)	70-160	Good	40000-90000	High energy savings, low O&M, long life, no mercury, high capital cost.

Street lighting installations normally use one of three types of High Intensity Discharge (HID) lamps: High-Pressure Sodium Vapor (HPSV), Metal Halide (MH), or Mercury Vapor (MV).

HSPVs produce a yellowish light, have a long life, are very energy-efficient, and have a consistent lumen intensity over a long period, but they have poor color-rendering properties.

MH lamps are the most frequently used as an alternative to HPSV in new installations. They are also quite efficient and provide much better color rendering. However, these lamps tend to have a shorter lamp life (some models below 10,000 hours) and poor lumen maintenance over the life of the lamp. Recent developments have shown improvements in these areas, but the improved lamps are presently limited in supply and higher in cost.

MV lamps are the least efficient of the HID types and have poor lumen maintenance.

Currently in the urban street lighting space, HPS technology is predominant in India. However, HPS lamps are generally regarded as being inappropriate for night lighting. Because of a reflector attached behind the lamp of an HPS, much of the luminance of the light is lost. This also produces light pollution in the surrounding area, which leads to inconvenient glare for drivers and pedestrians and this may cause roadways hazard.

Light-Emitting Diode (LED) technology is a fast-evolving technology with significant energy-saving potential. Operating for an average of 10 hours per day, LEDs have a life span of up to 13 years, and provide a pleasant spectrum of light. The lifetime and performance depends on quality of the LED, system design, operating environment, and other factors such as the lumen depreciation factor over a period of time.

Although the upfront cost of the LED is higher than the cost of most HID lamps, the energy consumed by the LED is half of the lamp's energy (or less) and LEDs last longer than conventional lamps, resulting in significant life cycle savings. The LED fixture does not require ballast or a capacitor; instead it converts the supply voltage to low voltage direct current, using a small electronic power supply.

The LEDs or induction light, emit a white light that provides high levels of scotopic lumens allowing streetlights with lower wattages and lower photopic lumens to replace existing street lights. For instance, a 30 W LED street light can replace a 70 W HPS lamp, while providing the same illumination (GRAH Lighting 2012). This ultimately results in significant energy savings. Under optimal conditions, LED can reduce energy by up to 60%. Further Energy Efficiency gains can be achieved by combining LED with adaptive monitoring and control technologies. While adaptive lighting can be too demanding for some cities at this stage, there are some easy options to reduce energy demand such as installing a timing meter, to switch lamps at some point of time. For instance, some cities may opt to switch off major parts of its street lighting after 1 am. However, it should be carefully evaluated whether this is an effective measure with respect to other pressing issues like security on the roads. Given that street lighting represents a significant share of a city government's budget for electricity application, LED street lighting presents an opportunity for becoming more energy-efficient and cost effective.

14.13 Intelligent Street Lighting Systems for approaching Road towards Railway Stations and Airports

Street lighting systems are not complete solution, if not integrated with automation and other intelligent features. Generally, it has been observed that an integrated smart street lighting system provides over 30% of extra energy savings. Also, it provides the O&M service provider with better control over the quality of the services. It gives the municipality better, dynamic remote management and faster outage response. This also helps them immensely in reducing their O&M costs over time.

Intelligent street lighting systems benefits can be categorized in two ways: energy savings and operational savings.

Energy Savings: Typically LED or other modern street lighting system with automation has biggest benefits of lower energy costs which results from following features:

- Low wattage: LEDs provide significant energy savings by delivering the same or enhanced quality light at lower wattages than legacy bulbs.
- Dimming: Because of their high light output, LED lamps can be dimmed as much as 50 percent when first installed with minimal compromise in light output. In addition, operators can schedule lamps to dim as circumstances allow, such as at low traffic times or in unpopulated areas in the middle of night.
- Reduced burn time: With on/off scheduling capabilities, operators can easily modify street light operation to coincide with changing sunrise/sunset times, reducing lamp burn time.

Operational Savings: The operational savings from networked LEDs will vary depending on the costs the street light operator currently incurs to maintain their lights.

- **Long life:** LED lamps last 3 to 4 times longer than legacy lamps, so require replacement less often, which reduces hardware and installation costs.
- **Remote monitoring and management:** Street light management software gives operators visibility into street light operations (for example, how much energy a lamp is using), as well as control over dimming and on/off schedules, reducing the need to run lamps for long periods, and deploying photocells.

- **Automatic outage detection:** Management software provides instant outage notification, dramatically reducing the number of calls (and related costs) to the call center and cutting downtime up to 90 percent. With accurate outage information, operators can eliminate truck rolls from false alarms, pinpoint nonworking lamps and quickly dispatch crews to specific lights.
- **Proactive maintenance:** These interventions help operator or municipal corporations to provide in time proactive maintenance to the citizen. Also, this results in extra savings for them.

Technological development has made it possible to have centralized automated intelligent street lighting infrastructure in our cities. **Table 14.9** provides the list of the options that are available to further enhance the quality of street lighting systems and gain further savings from the intelligent system in place. This also ensures that grievance redress mechanism is efficient. While designing the solutions for the street lighting infrastructure, ULBs and the experts should look at the financial viability of the CMC solutions, since some of solutions may not be commercially viable for the small or midsize projects. The solutions proposed should be critically examined to ensure sustainability.

Table 14.9 Proposed Automation and Energy Savings Systems

	Proposed	Purpose	Benefits
Solution 1	Dimming in off peak hours	Reducing the lux level as per the requirement of the outdoor lighting conditions	It will result in extra savings through adjustable lux level
Solution 2	Lighting automation with astronomical time switch control	Automatic switch to on-off the lighting feeder	It will reduce the human errors and will reduce the wastage. Also, will reduce O&M cost
Solution 3	Astronomical time-switch control-based lighting automation with flux stabilizers with astronomical control		Will reduce O&M cost
Solution 4	Astronomical time switch-based automation with remote control using GSM technology	This will lead to the establishment of remote monitoring	Centralized monitoring system can be set up over this technology, which will lead to more effective and responsive O&M.
Solution 5	A combination of solutions 3 and 4	This will lead to the establishment of remote monitoring	Centralized monitoring system can be set up over this technology, which will lead to more effective and responsive O&M.
Solution 6	Wireless controls	Both these technologies will result in having smart real time intelligent street light system, which will help in reducing O&M cost and be effective.	
Solution 7	GSM/GPRS-based controls		

City street lights not only provide security but are also integral part of vibrant city night life. Rapidly growing urban population and growing cities are putting lots of stress on city planners to manage and maintain public utility infrastructure and especially the ones which are directly operated by scarce electricity. The Robust Streetlight Automation Solution available with many lighting companies who can address these issues with advanced technologies, remote monitoring and control along with substantial operational electricity saving.

For efficient energy usage and better monitoring, individual control and monitoring of streetlights is necessary.

The proposed intelligent outdoor lighting system offers an end to end solution for Smart Street Lighting System. The solution includes dimmable street light control unit hardware, Feeder panel with Gateway and Web based application for remote monitoring & control. The system proposed is based on Ethernet and LPRF (Low Power RF) technology for establishing communication to server and enable data logging, monitoring and control.

In our automation system there is a Smart Outdoor Gateway referred as Street Lighting Gateway (SLG), which resides in the Lighting Feeder Panel and forms a small local group of Smart Outdoor nodes (SLC) with 1 node mounted in/on each streetlight/pole. SLG communicates with Smart software suit i.e Central Management Software (CMS), receives commands, decodes them and executes command by passing these commands to corresponding node in its network. General scheme of deployment of solution is as shown in below **Fig. 14.8**.

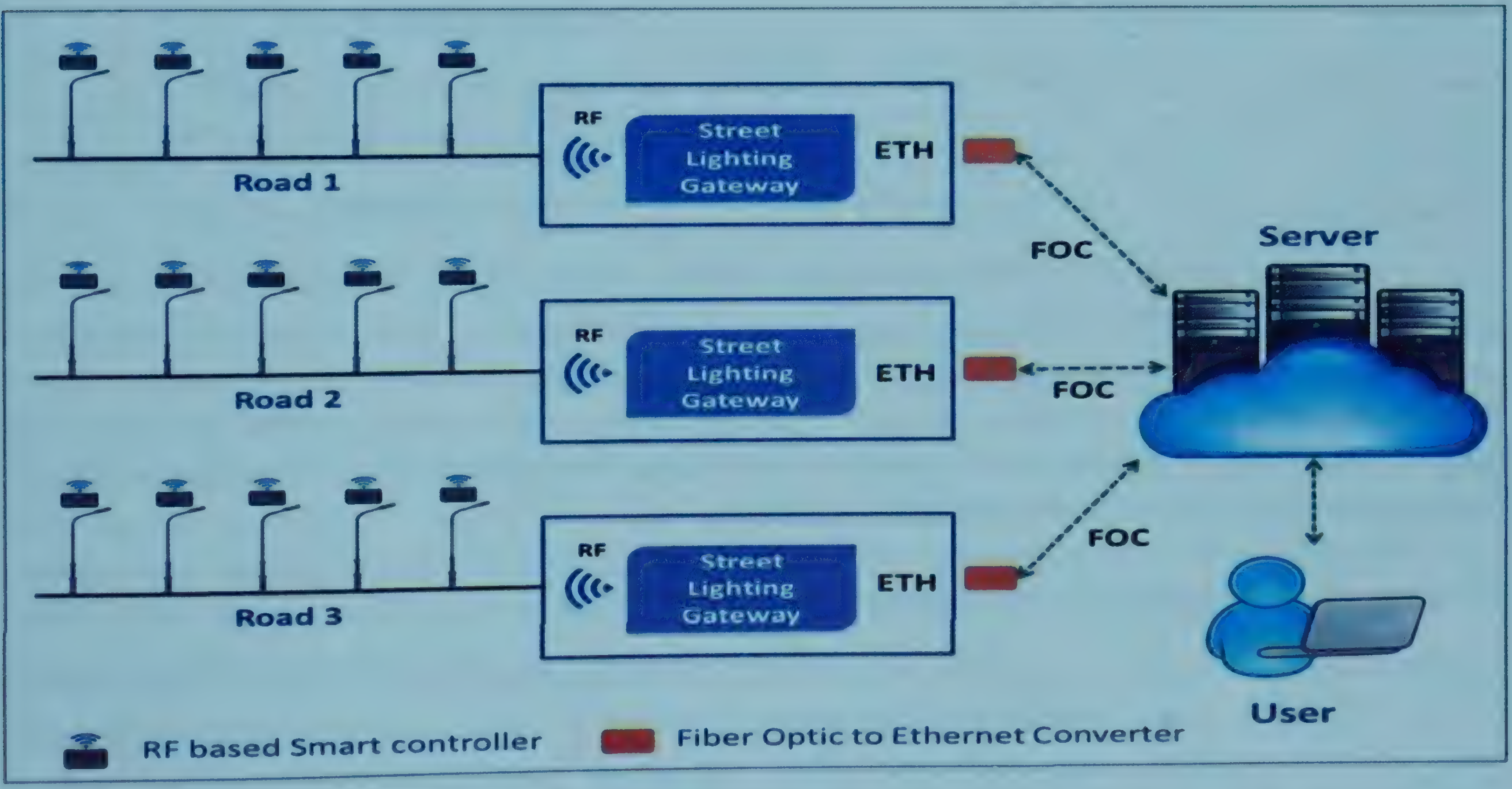


Fig. 14.8 RF based Individually Addressable Streetlight Management System

14.14 Technical Specifications for Smart Street Lighting

RF based lighting control system for Street Lights: ARF-based two-way communications between lamp Ballasts (drivers) and segment gateway controllers based on industry standards is proposed. Schedule dimming in street lights for long lamp life and energy savings also leading to reduced maintenance & operating cost. Condition Management via Smart Street Network in which parameters can be controlled with an easy to use interface.

Features of proposed system

- It has individual lamp level control with dimming facility. It turns On/Off Lights as per predefined schedule.
- It controls the Lights as per Astronomical Time clock for Sun Set and Sun Rise times. Dimming of Lights at Non-Peak Traffic Hours.
- It has 24 x 7 Online monitoring. It supports failure reporting.
- It generates electrical data, event & failure reports of the LED load.

System Components

The following are the main components of the Smart Street Lighting System:

- Smart Outdoor Node - LPRF Enabled
- Lighting Feeder Panel with inbuilt LPRF Gateway
- CCMS Software (Smart Street Network)

Table 14.10 General Function of the System

Control	Monitor	Protection/Alarm
Lamp On/Off	Input Power	High Input Voltage Current
Dimming (10-100%)	Supply Voltage, Current, Power factor, Energy Consumption	Power factor, over voltage, overcurrent, Harmonic distortion,
	Lamp Voltage, Current, Status, burning hours	Over Voltage, under voltage
	Lamp Operating hours	

Table 14.10 shows that even during the dimming phase, the system can monitor many different lighting conditions and different protection facilities.

RF Mesh based Street light Management System

System consists of 2 main hardware components, Street Lighting Feeder Panel with inbuilt Smart Outdoor Gateway which acts as a bridge between lamps & central server and Smart Outdoor Node which is mounted in/on each street light. The feeder Panel power up the street lights. It mainly consists of Input side MCBs, Energy Meter, Contactors and the gateway. The Smart Gateway forms a small network of smart outdoor nodes. Smart Gateway receives commands from Central Management Server (CMS), issues these commands to Nodes, collects data from them and conveys this data to CMS. Users can access this system via website from any computer in same network. Main features and specifications of various system components are given below.

Smart Outdoor Node (Street Light Controller)

The Lighting Control Node is a RF based assembly for the LED lamps. It provides addressability, energy saving, control and problem identification. Individual control for lamps can be obtained from the distant command center. Radio frequency based Lighting Control Gear assembly will be used for Controlling, Monitoring & Data acquisition of lights. The lamp will communicate with the system via RF Frequency

- It enables schedule to dimming & control the consumption of electricity.
- It enables in reducing the down time & ensures maximum uptime by monitoring power parameters of each lamp.
- It provides reliable long range wireless coverage up to several hundred of meters per hop.
- It has dimming capability using 1-10V Lighting control.
- It has a built-in metering engine which will capture and provide reports in real time energy metering parameters as well as records the historical usage type data such as energy consumption (KWh) and lamp/device running hours.

Outdoor Nodes conforms to the following parameters

- AC Voltage: 140-270V
- Mains Frequency: 50-60Hz
- 1-10V analog dimming
- Remote switch on/off, maximum internal 5A relay outputs
- With dimming interface: 1-10V

14.15 Bus Stop Areas

Bus stops should be located adjacent to a street light to provide lighting for the immediate area. Additionally, shelters should be internally lit, preferably using solar power. Locations of bus stops in urban areas should be selected on the basis of whether adequate lighting is available on roadways and walking paths approaching the stop. Bus stop board and alighting areas shall be connected to streets, sidewalks, or pedestrian paths by an accessible route. Lights should be housed in a protective casing to reduce vandalism, and directed so that they illuminate the waiting and boarding areas. City Bus stop shelter can be lighted by backlit advertisement panel and Bus Stop Area should be lit up with the Stand Alone Solar LED Street Lights on GI Pole of 4 Meter eitherside of the Bus Stop.

Luminaire selection

- Here solar street light type luminaire is recommended (**Fig. 14.9**). Because here all the time one does not need the light output, So solar street light type structure will be very beneficial in this case.
- Smart Integrated Solar All In One with > 140Lum/W, MPPT Charge Controller, Lithium Ferrous Battery, Tiltable LED panel, Adjustable AIO mounting angle, Mono Crystalline Solar Panel, PIR motion Sensor, easy to install.

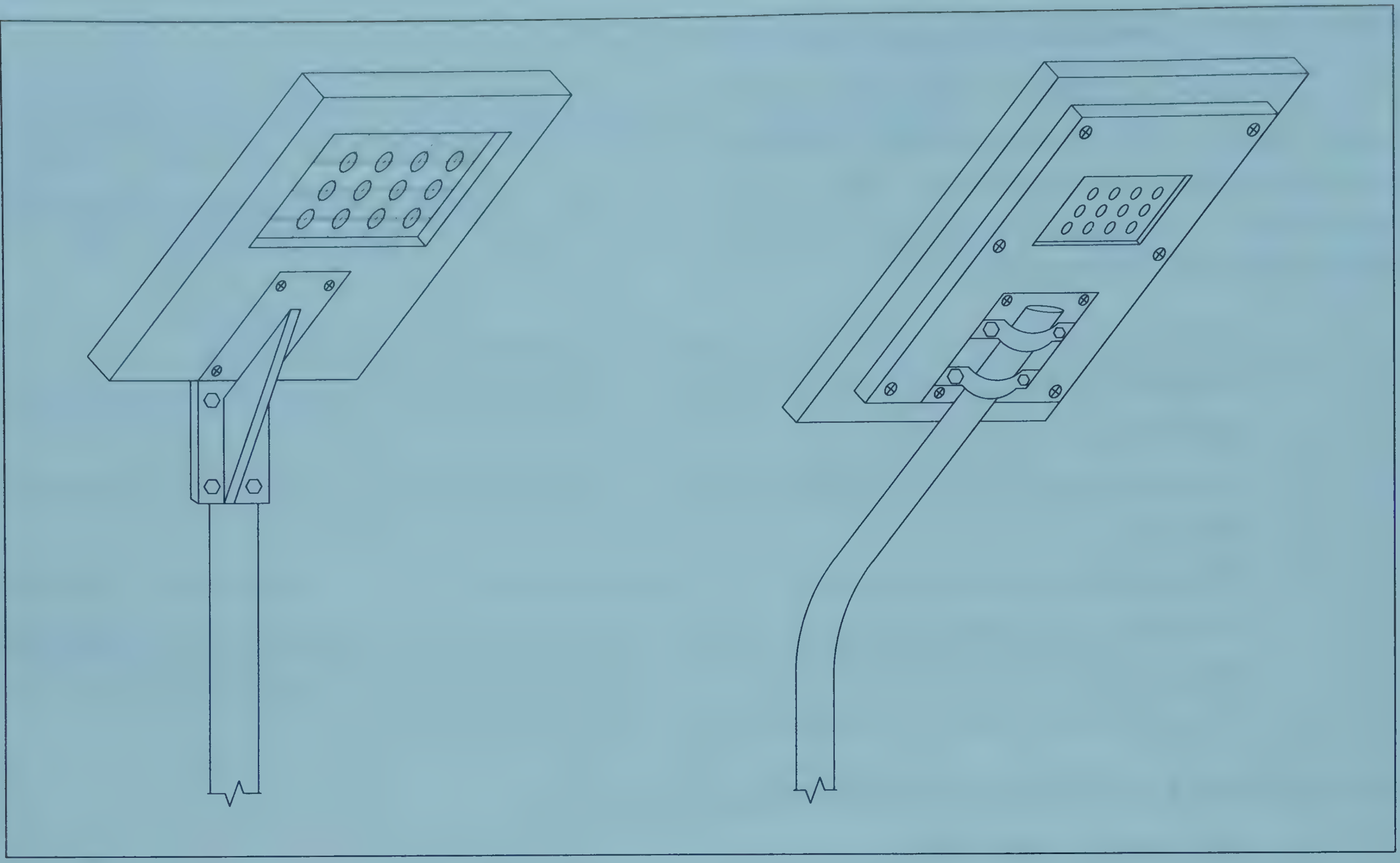


Fig. 14.9 Luminaire Selection

14.16 Lighting for Pedestrians Walkway

Multi Utility Zone (MUZ): MUZ is the dedicated space on the street where in all the stationary element are organized in obstruction free manners. Stationary elements like trees, hawkers, bus stops, underground and overhead utilities like electric supply, light poles etc, parking and such other elements are organized in a space on shoulders between footpath/cycle track and motor vehicle lane.

Right of way (RoW): Right-of-Way is a type of easement granted or reserved over the land for transportation purposes, this can be for a highway, public footpath, rail transport, canal, as well as electrical transmission lines, oil and gas pipelines etc.

Street lights should ensure adequate lighting of the entire right of way. Trees or advertisement hoardings should not impede illumination on the footpath. Spacing between two light poles should be approximately three times the height of the fixture to ensure complete lighting. Light poles should be no higher than 12m to reduce undesired illumination of private properties.

Table 14.11 Street Light Height and Spacing as per Street Type

Street type	Pole height (m)	Spacing (m)
Footpath or cycle track	3-6	9-16
Local street (less than 9m width)	8-10	25-27
Arterial or Collector (more than 9m width)	10-12	30-33

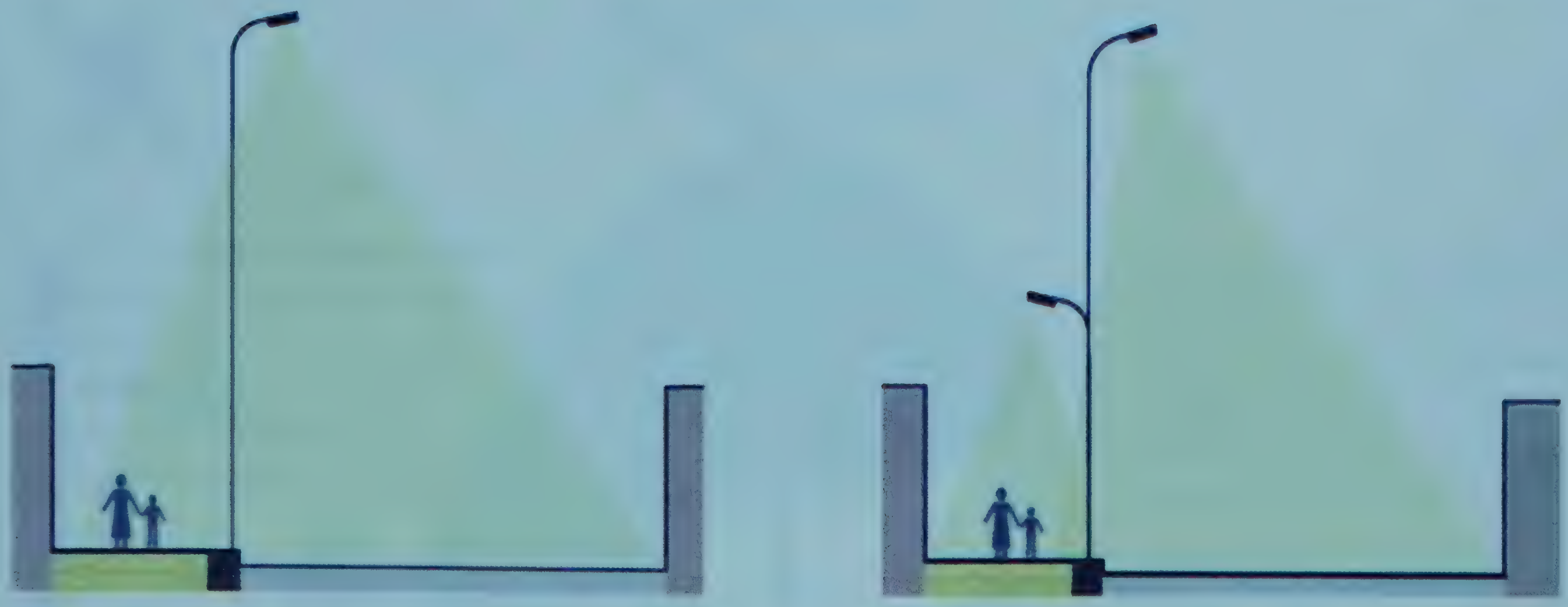


Fig. 14.10 Street Lighting on Narrow Streets

A single light in the MUZ can be used if it illuminates the entire RoW width (upto 12m). Additional pedestrian light should be fixed at a lower level on the same pole if lighting is insufficient. (See **Fig. 14.10**). For RoW ≥ 24 m, pedestrian and street lights can be combined in a single pole in the MUZ to avoid clutter, provided there is proper illumination (**Fig. 14.11**). As an alternative, median poles can be used for the carriageway and pedestrian lights should be provided separately.

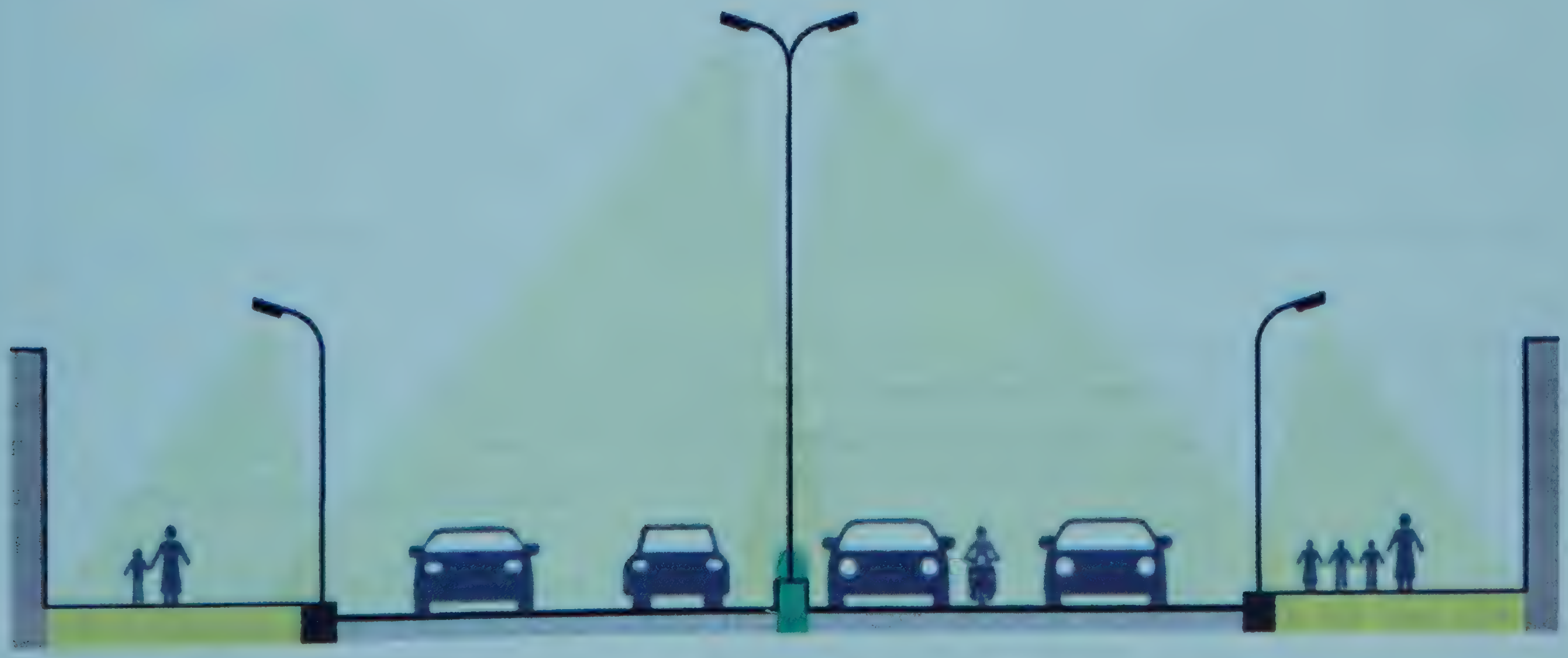


Fig. 14.11 Street Lighting on Wide Streets

It is recommended to use only LED for street lighting due to its low energy. Solar lighting systems should be encouraged, subject to economic and security considerations. These guidelines are generic recommendations. A lighting consultant may be engaged to contextualize these, determine the necessary lux levels, and develop detailed designs.

Fig. 14.12, shows the dark spot created by trees, if the position of the light post is not coordinated properly.

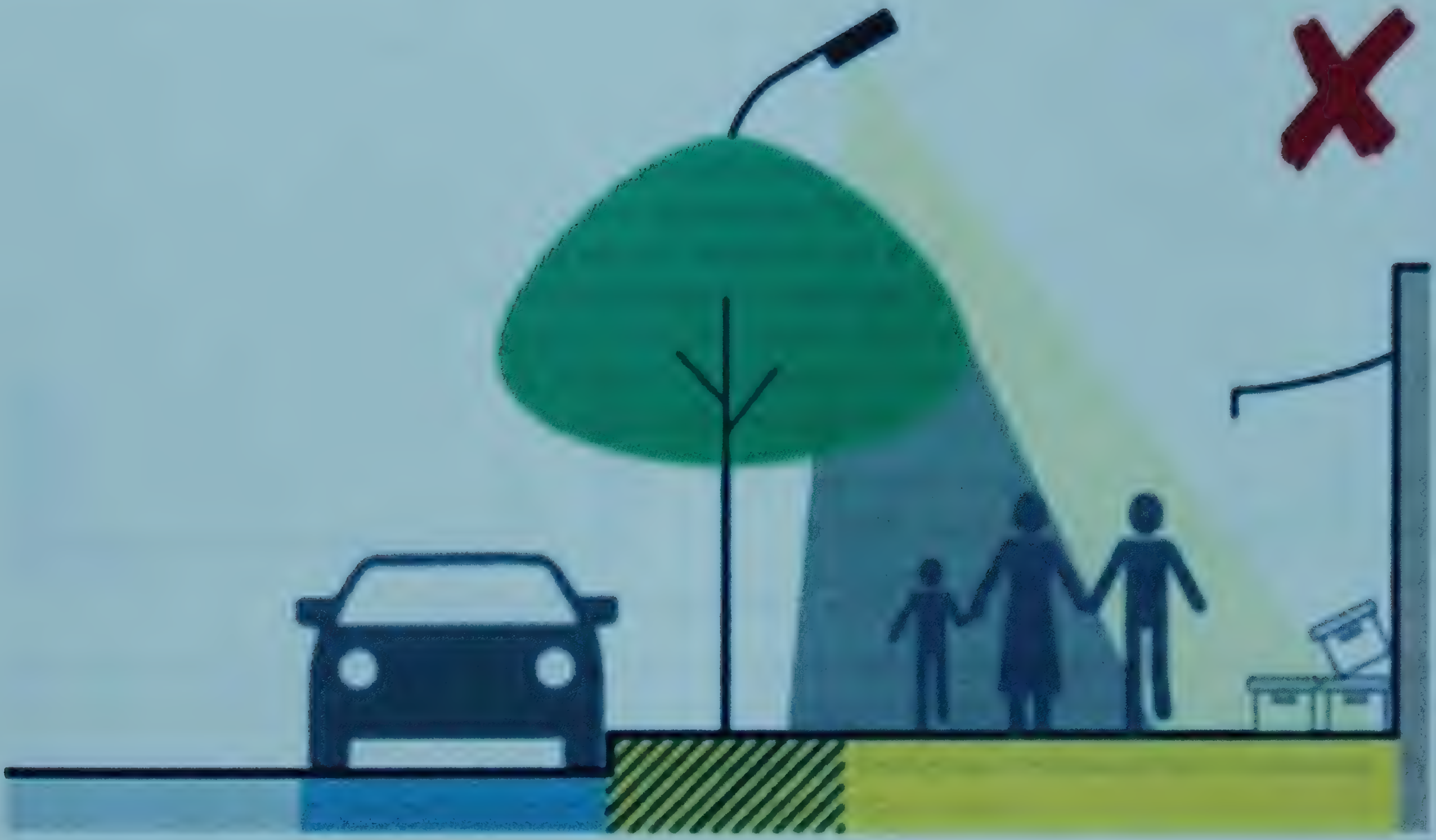


Fig. 14.12 Placing of Street Lights should be placed coordinated with Trees to avoid Dark Spots

CHAPTER 15

PLANTATION AND LANDSCAPING

15.1 Introduction

Road corridors provide a vital link for transportation. They carry the onus of sustaining the ecological distinction and critical biodiversity of fragile ecosystems along their corridors. Development of Green Corridors along highways mitigates potential losses due to inevitable felling of trees and construction impacts on the surroundings. Urban road corridors are equally important areas for sustainable plantation to save rapidly degrading natural, cultural and heritage landscapes, plant and wildlife corridors and endangered habitats.

15.2 Landscape Approach

Ecosystem services that landscape and plantation provide include groundwater recharge through infiltration; flood protection through reduced runoff, and soil stabilization with planted swales and embankments; food, fuel and timber for the local population; and, contiguous green corridors that enhance biodiversity through connectivity for wildlife migration. Through reduction of ambient temperatures in the micro-climate created by plantation, climate change impacts are significantly reduced, with more optimal thermal comfort along the roadway corridors.

Plantation mitigates heat island effect on hot reflective roads; checks soil erosion; creates shade; protection from the elements –wind, rain, slow and hail; enhances important views, and creates visual respite.

Pollution mitigation benefits include particulate air and dust pollution filtration through plantation-known to be natural sink for air pollutants and carbon sequestering; carbon monoxide reduction; noise buffers to and visual buffers from surrounding areas.

Plantation also prevents glare from the headlight of incoming vehicles and moderates the effect of wind and incoming radiation.

Wayfinding cues through repetition of plantation, highlighted specimens at curves and openings, variety through colour, form and habit respond to functional considerations and a pleasant driving experience. It also gives employment to the local populace. And, is a representation of the regional biodiversity of a corridor.

15.3 Landscape Development Process

Highway design and landscaping are integral and complementary. They must be designed and detailed with specifications by qualified technical consultants, including civil engineers, landscape architects and horticulture experts. Comprehensive planning is recommended with due consideration to the technical, spatial, environmental, social and cultural needs inherent in the corridor landscape. This approach would include-

- Site Inventory and Analysis
- Road Alignment and Landscape Impact
- Design Intervention and Ecological Restoration/Remediation of Existing and Proposed Landscapes

- Planting
- Monitoring and Maintenance

15.4 Site Inventory and Analysis

Land Acquisition : A typical road cross section comprises of the carriageway, medians, intersections, shoulders, embankment slopes, kerb edges, drainage, pavement and roadside land (**Fig. 15.1**). During the land acquisition phase of road projects, the proposed landscape development such as roadside plantation, medians, traveller amenities, and relevant contextual issues should be planned. Acquisition of additional land may be required to provide flatter side slopes for cut and fill along with contouring of the adjacent land. And also, space for suitable planting as well as parking, look-outs and other amenities.

Sufficient widths for roadside and median planting for all ROW should be included in planning for land acquisition, unless specific site conditions limit it. These planned areas will provide the framework for screens, buffers and shading, as required in the overall plan in the future.

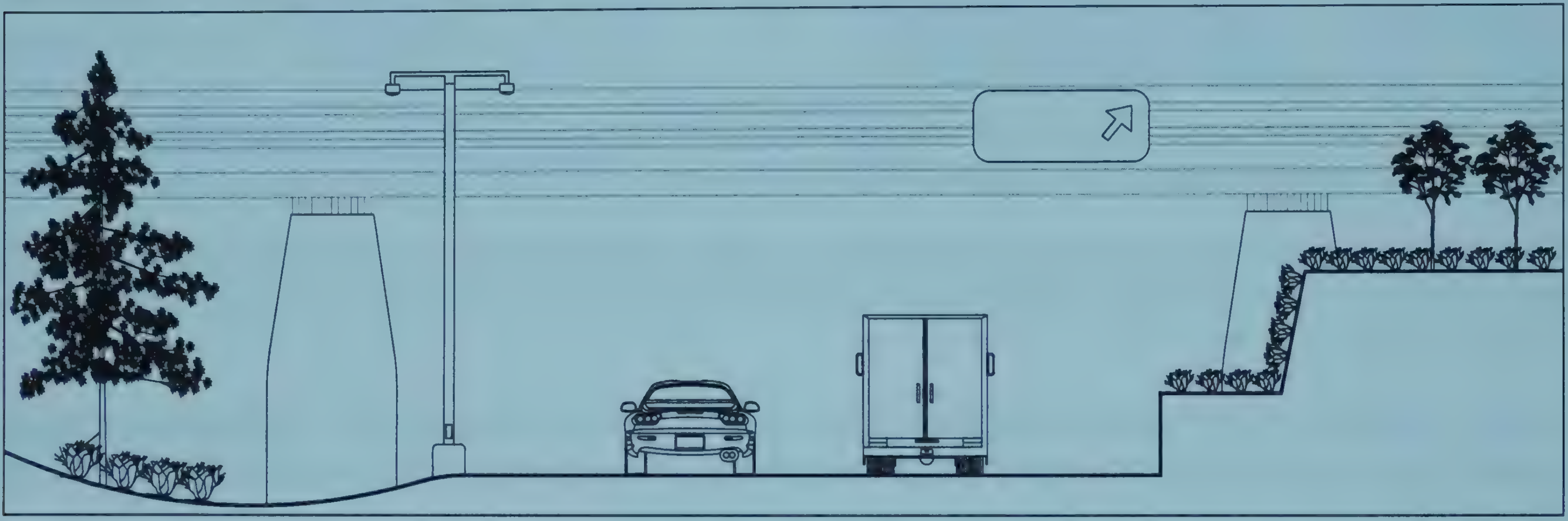


Fig. 15.1 Typical Road Cross-section with Planting, Swales, Site Furniture, Carriageway and Retaining Walls *(Source: Timesavers Standards for Landscape Architecture)*

Conservation of Land Values: Existing natural or manmade landscape features and plantation should be preserved, protected and integrated in the road landscape to the extent possible. This includes natural woods, streams, ponds, rock outcrops and scenic vistas. Spacing of carriageways can be divided to preserve natural features, if required. Also, significant heritage and culturally relevant areas should be identified, documented and protected. Road corridors, such as those connecting airports into Central Business Districts (CBDs), and those connecting historic precincts, are ideal sites for landscape enhancement.

Regional Variations: Topography, soil, climate- rain, humidity and temperature, physiology, solar aspect and operational considerations vary by region, state, city, and sometimes are corridor specific. As a result it is not possible to follow uniform standards for landscaping. While site specific treatments vary, outline specifications may be followed. Inappropriate treatments impact drainage, run-off, erosion, wind tunnels, slickness etc.

Surroundings: The design of roads vary by location.

Urban roads have restricted ROWs, and land available for plantation and greater requirements for buffers and pollution mitigation. **Table 15.1** highlights the landscape considerations.

Table 15.1 Landscape Considerations

Open Space	For recreation, utilities and services
Planting	For screening, shade and pollution mitigation and reduced glare on multi-lane roads
Screening and buffers	For schools, hospitals, residences and also unsightly views and sound
Edge Conditions	Gutter and kerbs or retaining walls along slopes
Drainage	Structured drainage with rainwater filteration
Site furniture	Light poles, Signages, Benches, Trash Cans
Signage	Directional, informational and safety
Services	Footpaths, cycle tracks, rotaries, utility lines and manholes etc.
Other Considerations	Cost and scarcity of land and limited ROW, multiple access points
Legal Considerations	Zoning

Composition of the landscape should vary by speed of road. For arterial roads, greater spans of contiguous planting are possible, whereas for collectors more detail is discernible and hence variation in the landscape is welcome. Safety through visibility and predictability is important in both scenarios. Road construction accelerates land values and commercial and industrial activities, but also increases noise, dust, fumes from traffic. In this situation, buffers for the adjacent land uses through screen plantation are required. And, the local setting, its people and culture should be respected.

15.5 Road Alignment and Landscape Impact

Geometry of Road with respect to landscape: Roads should be designed along the existing topography and not cut through the terrain, to avoid adverse impacts on local watersheds. Respect the natural terrain, balance cut and fill, stabilize the embankment with plantation and/or retaining walls to prevent soil erosion. An integrated planting and drainage strategy across the ROW cross-section is required for optimal road development and long term efficiency.

Horizontal and vertical road alignments, road curvature, cross slopes, corridor width, structures including bridges, retaining walls, road furniture such as signages, signals, lighting system etc. have to be integrated into a comprehensive planning strategy at an appropriate scale. The objective is to create minimal impact using gradients, curves and sight distances such that the road harmonises with the existing landscape. Road alignment with larger radii, spiral transitions or coordinated curves need to be supplemented by contouring and planting on both sides.

Protect existing vegetation: Tree felling should be at a minimum, with greater emphasis on protection of older mature trees with wide canopies to protect the biodiversity it supports. Invasive, non-native trees can be replaced, preferably in a phased manner, to prevent total loss of tree cover. Compliance to Forest Conservation Act and local laws is a must.

Transplantation: Transplantation of trees may be carried out to save mature trees along existing ROW, within a viable distance of its existing location. Transplantation should be scheduled based on the season, expertise and specialized equipment with adequate and careful planning, execution and post-transplantation care.

Site Amenities: Roadside amenities include scenic lookouts, bus stops, transport terminals, rest areas, toilets, and service stations. Site furniture including benches, trash cans, lamp posts, signage to be incorporated with plantation. The objective of plantation should determine the planting pattern. For example, shade for parking areas; fruit groves along rest stops or in the suburbs for produce and passive activities; screen plantation for noise buffer; low hedge plantation for safety with visibility from recreation areas.

Plantation must avoid conflicts and barriers to legibility and/or accessibility. Planting large shrubs in front of signages or blocking blind turns can create accident hazards. Continued maintenance of shrubs and tree branches to ensure that hazards are not created.

Future Considerations: Future road widening plans to be considered during plantation in the ROW. Planting, particularly of trees, should begin after the space for planned expansion. Low and medium height shrubs planted can be easily transplanted, so are more appropriate.

Where trees are planted with shrubs and groundcover as saplings, a revaluation of understorey plantation to be undertaken every 3-4 years. As the trees grow, sun exposure will change, most likely reduce, and the viability of sun loving plants will change. These will need to be replaced with shade plants. The changing surroundings too will determine evolving landscape needs, be it screening, visibility, pollution mitigation, erosion control or shade.

15.6 Plantation

Plantation should be designed based on the full maturity trees will achieve. Species to be decided based on the physical growth characteristics of trees, like form and shape, foliage pattern, growth rate, branching pattern, soil characteristics and conditions of the strip like water logged areas etc.

Tree selection is based on the following factors-

- Objective of plantation
- Plant form, habit and size
- Planting pattern- avenues, clusters, groves, specimen
- Sight lines required and protection from glare possible
- Texture and colour of foliage/flower/fruits in different seasons and stages of growth
- Adaptability and suitability to agro-climatic regions/zones
- Growth rate (slow/fast) average age of maturity and replacement cycle
- Maintenance required for sustenance and growth
- Economic and other social/recreational benefits
- Drawbacks and demerits if any, like prone to insects/pests disease, animal grazing and human interference.

To maintain desired visual and aesthetic quality, use shade and buffers. Homogeneous stretches may be developed based on landscape corridor available, topography, climate, and soil conditions. These should be limited in the use of a single species to avoid the possibility of high casualty in case of disease or low tolerance to site specific conditions.

(For example, monoculture street tree plantations of Elm trees saw catastrophic losses of over 25 million trees in Britain and over 40 million in the US due to the Dutch Elm Disease in the mid-20th century. They devastated the landscapes of cities across the Northern Hemisphere, where there were planted along roads, walkways and hedges because of their overarching form and shade.)

Clear Sight Lines: Plantation must occur outside of required sight lines, particularly at intersections, curves and blind turns. Where visibility for safety, surveillance and pedestrian movement is required, high canopy trees with no shrubs or groundcovers are suggested. Trees with high branching and crowns provide better visibility and are preferable (**Fig. 15.2**).

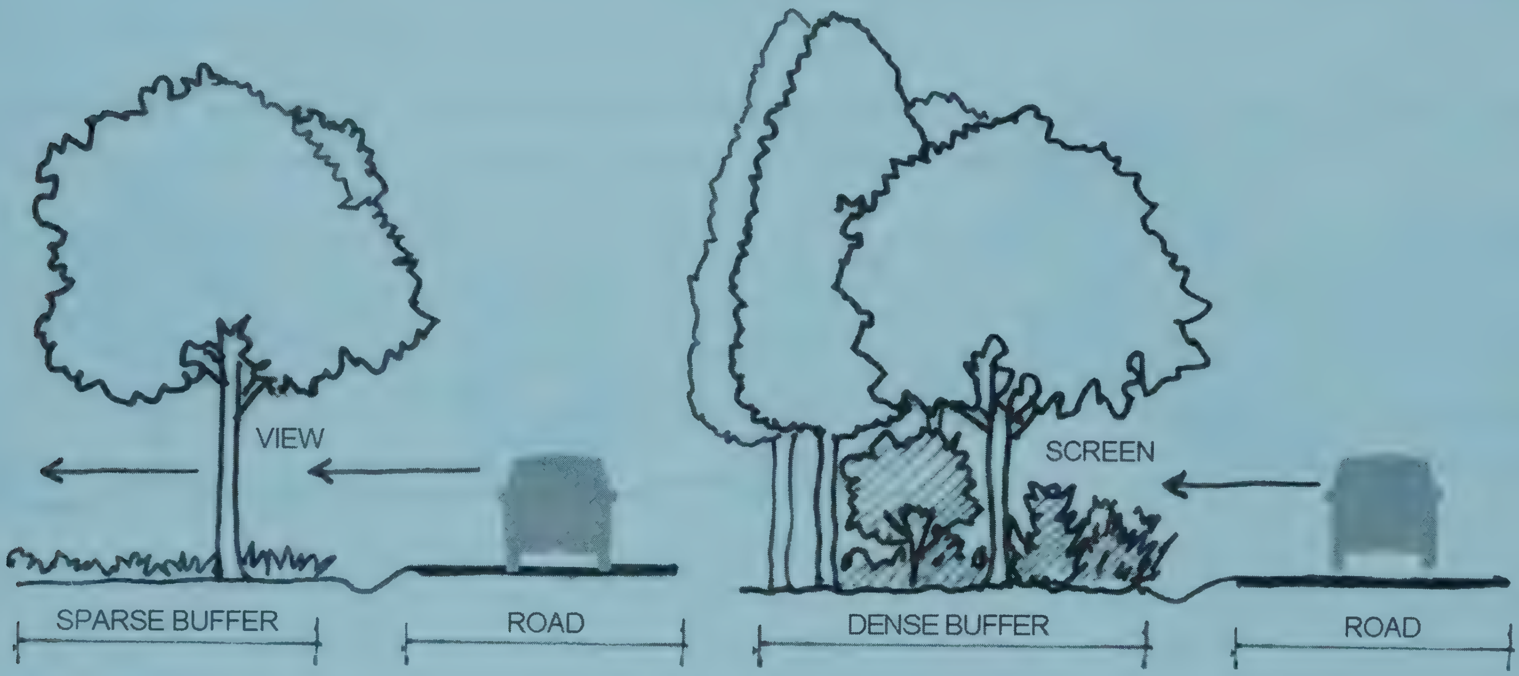


Fig. 15.2 Visibility to the surroundings depends on the Planting Structure

Heat Mitigation : Large shade trees along circulation routes, with overlapping mature tree canopy filter out the sun. Trees that retain their foliage longest are preferred to deciduous trees.

Visual Enhancement: For aesthetic views, soften built edges with plants and create openings between pockets of continuous vegetation.

Avenues with single species along high speed routes are legible for defined lengths of stretches. For short stretches, diversity of planting, specimen trees, flowering and fruit bearing trees may be used.

For urban roads, it is important to address the need for safety, lower speeds to create a balance between vehicular and pedestrian movement, neighbourhood or local context, aesthetic consistency, accessibility, as well as resilience and long term sustainability. Non-toxic planting with minimal fruit litter, mature tree canopies to reduce hear absorption, clear intersections and turning points to maintain safe sightlines and variations in planting for interest and identification will encourage pedestrians to use streets as public spaces.

Screening: Highly Industrialized Areas, places of critical biodiversity and quiet settlements require buffers from the road. As do urban neighbourhoods, hospitals, schools etc. (**Fig. 15.3**).

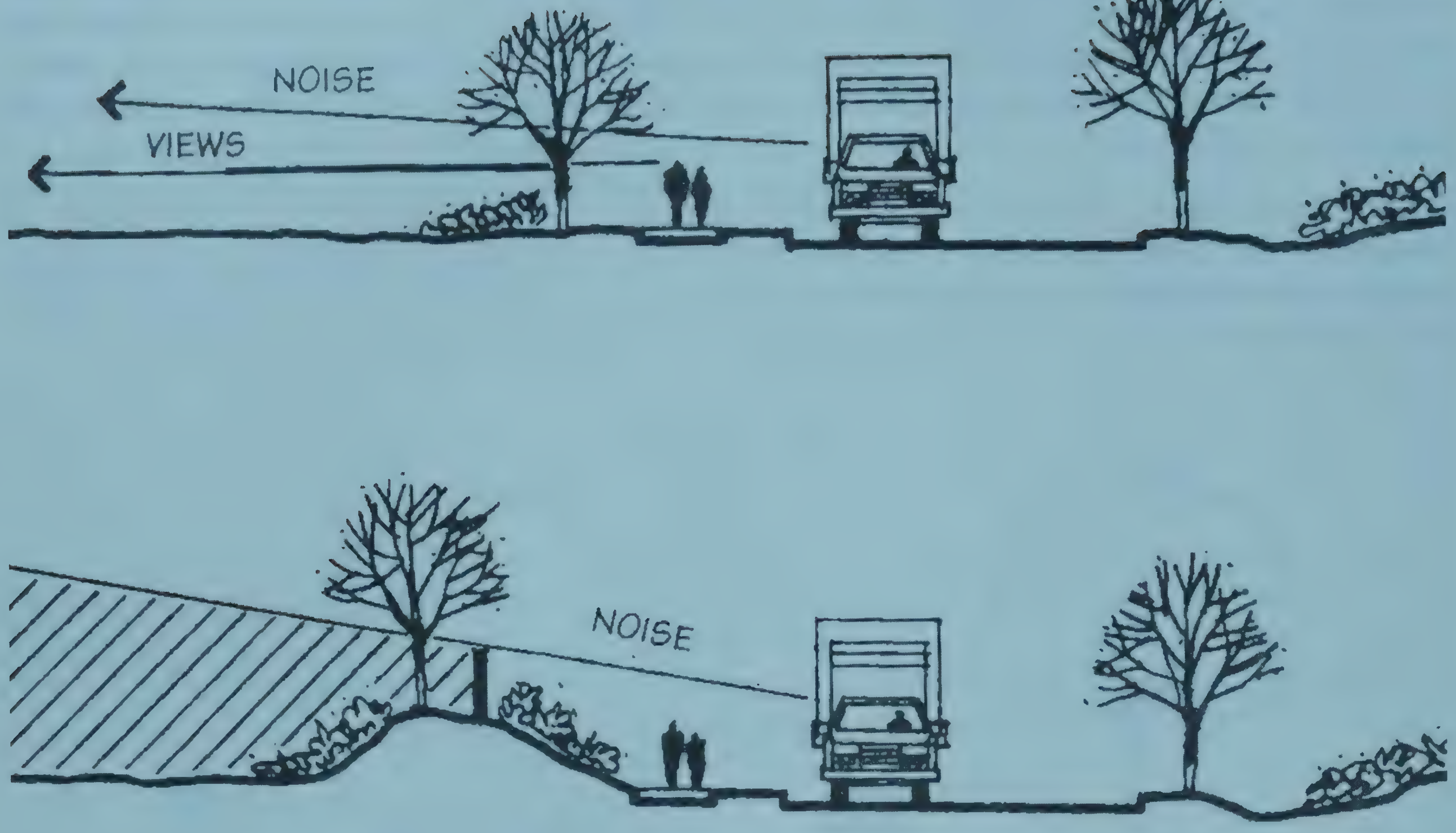


Fig. 15.3 Views to distinct natural features can create Scenic Drives

Nuisance Factors: Trees with long gestation period, rapid growth and a capacity to resist fungal and insects attack form ideal avenues.

Shrubs and groundcovers used may include thorny and toxic plants to repel stray animals and damage, particularly in long stretches and medians with no access.

Where buffers- physical, visual and/or noise barrier from the surroundings are required, layered, hierarchical planting with multiple rows of trees and shrubs is suggested. Plants that obstruct movement, create extensive leaf and fruit litter should be avoided in pedestrian areas. Shrubs/ trees to be clear of side drains. Root system should not interfere with working of drainage facilities.

Glare reduction: Overlapping tree canopies, with reduced exposure to the glaring sun will help reduce glare. Median planting to comprise shrubs of low and medium heights to reduce glare from oncoming traffic at night.

15.7 Plantation Palette and Selection of Species

Native trees and plant material should be used as much as possible. Native plants are plants indigenous to a given area in geologic time. Removing a certain native plant from the landscape will likely remove the insect that feeds on that plant, which in turn may eradicate the bird that feeds on that insect. The loss of a species can quickly escalate to affect an entire ecosystem.

Non native species including exotics (that do not replicate easily) and invasive should be avoided. An invasive species is a non-native species that does not naturally occur in a specific area and whose introduction does or is likely to cause economic or environmental harm or harm to human health. (Acacia mearnsii (wattle), Eucalyptus globulus (eucalytpus), and Pinus patula (pine) in the Western Ghats, Chromolaena odorata in Odisha, Alternanthera philoxeroides, Cassia uniflora, Eichhornia crassipes, Lantana camara, Parthenium hysterophorus and Prosopis juliflora (vilayati keekar) across the country.

Prosopis, for example, today covers 1.8% of geographic land of India, since its introduction in 1877 by the British. It is responsible for loss of native biodiversity, productivity of arable lands, ground water loss and water loss in canals and reservoirs across the country. It requires aggressive eradication and replacement.

Ornamental native plantation, particularly flowering ones or with distinct form, may be added to highlight key stretches, areas or nodes or used in the first row of avenue trees.

Native shrubs, grasses and groundcover recommended for understorey and slope stabilization can be locally sourced, require little maintenance and enhance the biodiversity benefits. Turf, meanwhile, requires intensive maintenance, watering, weeding, pesticides and limits indigenous plant and animal habitat, and should be planted sparingly. **Table 15.2** summarizes key concepts for planting.

Table 15.2 Key Concepts for Planting: Do's and Don'ts

Do's	Don'ts
• Native plants for adaptability and environmental benefits	• Invasive species
• Provide plant species to attract habitat	• Monocultures
• Prioritize drought tolerant species	• Chemical fertilizers and pesticides
• Create hierarchical planting schemes	• Long stretches of similar species
• Allow for adequate root protection	• Low branching/litter in circulation areas
• Integrate plantation strategy with rainwater harvesting and groundwater recharge system	• Compromising safety and security through overgrowth

In areas of degraded landscapes and wetlands, pioneer grasses to be introduced to create functioning wetlands which will then fix the soil pH and allow the growth of the entire planting structure of trees, shrubs and groundcovers required to sustain biodiverse plant and animal species.

15.7.1 *Tree Species*

Common species, which are typically planted almost throughout India include Terminalia arjuna (Arjun), Tamarindus indica (Imli), Syzynium cuminii (Jamun), Madhuca indica (Mahua), Mangifera indica (Mango) Azadirachta indica (Neem), Ficus religiosa (Peepal), Ficus infectoria (Paker) and Dalberjia sissoo (Sheesam).

However, this is only a small sampling of the available trees that are suitable for road planting. Other recommended species that should be included are native trees that require minimal maintenance, have increased hardiness and protect and enhance native biodiversity. India has over 160 native trees, of which only 30 are typically used along roads, of which 6-7 are exotic species.

Urban road corridors are the ideal setting to diversify the species selection and give home to native trees and their supported ecosystem. A few examples are Sargooro, Kankero, Kharo jall, Roheda, Kummath and Khejadi. Region-wise specific plant species lists must be made with the help of landscape architects, ecologists and local experts from the Forest department and Horticulture department for use.

15.8 Plantation Typologies

Roadside Plantation: The first row of avenue trees along the ROW for all roads, should be large canopy, flowering trees 15-20m in height and broad canopy to provide shade to the road. Spacing to be 3m for dense buffer and 5-8m for visibility through the trees. For narrow roads, smaller species can be used with smaller canopy. A clear area of 1.5m from the carriageway to be maintained for clear sightlines. Rainwater filteration beds along the carriageway can be created within the 1.5m setback using grassed swales.

At wide curves, stopping sight distance should be clear and planting set back. High canopy trees with clear height of 4-6m from the ground to branching height will avoid hazards to tall vehicles and views along the carriageway.

Shrubs, grasses and groundcovers can be planted based on circulation, visibility and buffers required.

Native grasses should be planted along the road edges, medians and embankment slopes. This will increase the biodiversity in the area, reduce the costs, pesticides and maintenance required for turf and other exotic plants. A natural drainage swale at the top and bottom of the slope will carry the rainwater runoff and reduce formation of gullies.

One of the main objectives of roadside planting is to provide shade. In urban or other areas with space constraints, trees may be planted on one side of the road or alternating, based on the direction of the sun, preferably in the south and west directions. Or in a staggered alternating pattern. These tree species should be of local significance and should be mostly evergreen in nature, with minimal leaf-fall in winters to prevent blockage of roadside drains.

For medians widths, shrubs of low or medium height for prevention of the headlight glare to be planted (**Fig. 15.4**). This includes flowering shrubs in different sections, based on the visual aesthetic proposed. The shrub species typically proposed in the median are Bougainvillea and Thevetia nerifolia (Kaner). However, other suitable species should also be planted in consultation with the local horticulture specialists to avoid monocultures.

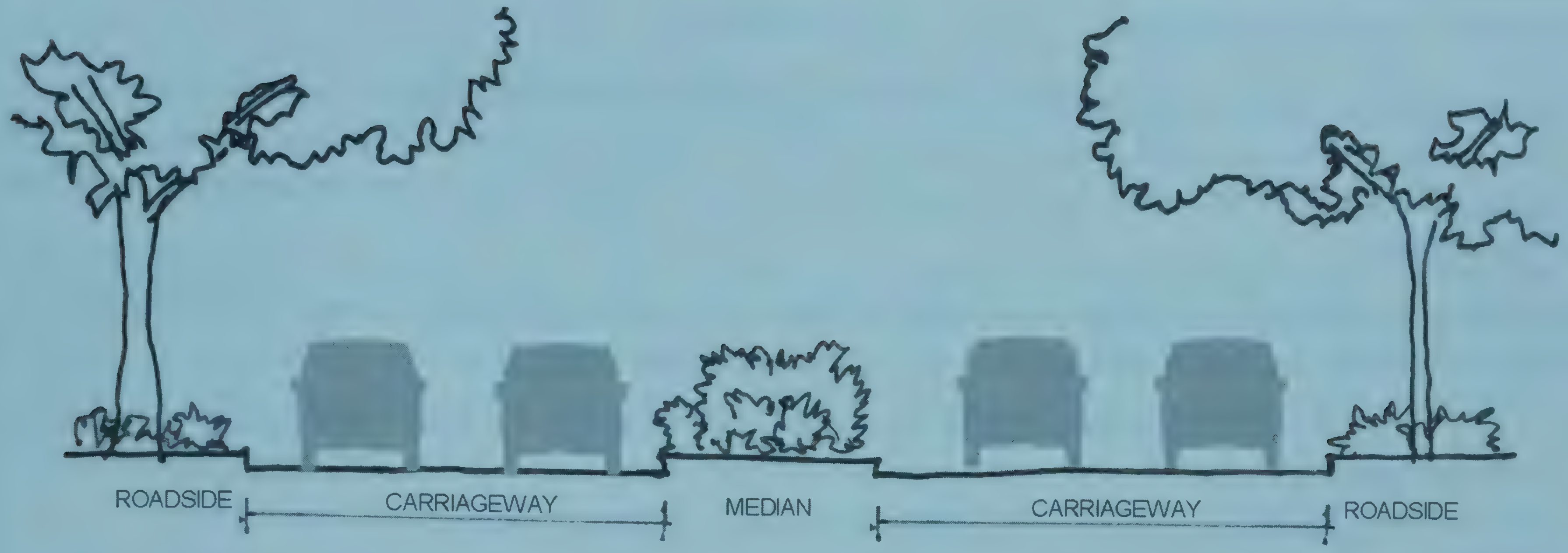


Fig. 15.4 Typical Urban Road Cross- section with Median and Roadside Plantation

At median cuts, grade separator and blind turns 1m space to be left for clear sightlines.

Roundabouts, Intersections and Site Amenities: Junctions should be planted with low shrubs and groundcovers without compromising sightlines or obstruct movement and surveillance.

Barring the clearance required to maintain sightlines, the roundabouts can be used for native planting, based on any designed landscape concept, integrate rainwater harvesting and/or provide a venue for sculptures, site furniture and passive recreation.

In urban areas, distinctive spaces for gathering and physical activity, with site furniture and shade planting with adequate visibility for safety and buffered from unsightly views can be detailed.

Landscape Treatment for Special Areas: Waterlogged Areas and Sandy/Desert Areas require site appropriate treatment. Aquatic plants in water logged area with successive plants for wetland areas along the low areas and drainage runoff to be directed towards these low lying areas. Around water bodies, to prevent erosion, soil stabilization planting is essential.

Desert planting to be minimal with use of xerophytic planting and key areas.

15.9 Protection Measures

At the time of establishment, tree plantations require protection from extreme climates and vandalism using removable iron/brick tree guards. Locally available bamboo guards or thorn fencing may also be used where protection can be ensured through these. Tree guards provide support to the tree and prevent animals from trampling or eating it. Once it is established with calliper of 150mm or more, and able to support itself, the tree guard must be removed.

Post establishment, trees need to be protected during road widening and/or pavement repair and work. Tree guards can be used. No construction debris, or equipment should be stacked near the tree, to avoid strangulation. An area of up to two (2) m diameter needs to be kept clear of hard pavement, with planting below sight lines. Tree grates or porous paving may be used instead to facilitate pedestrian movement, as required in urban areas.

15.10 Long Term Plans

Maintenance: Landscape planning and development to be carried out in a holistic manner with inputs from landscape architects, ecologists and civil engineers with expertise in the particular region. Planned stretches to have oversight from local experts and with engagement from the local people.

Horticulture maintenance work for existing landscape features for groundcovers, shrubs, hedges, topiary trees and avenue plantation in the specified areas require-

- Sourcing native vegetation to meet specifications of form, hardiness, habit and character.
- Create local nursery for sourcing, procurement and plantation.
- Set up a maintenance schedule for watering, weeding, replacement and organic fertilizer use for the first two years, and skeleton maintenance schedule for the subsequent years with a local agency. Allow for adequate fund allocation for maintenance.
- Schedules to be based on climatic and soil preparedness of the region. Re-evaluation and replacement schedules to be set in place and carried out.
- Monitor progress of planting and status of plantations on continuous basis. Carry out site visit for field verification in respect of survival, growth and size of plantation and maintenance of the same.

CHAPTER 16

SAFETY AND TRAFFIC CONTROL DEVICES

16.1 Introduction

With expansion and upgradation of road network, as well as, in the level of motorization and urbanization in the country, fatalities due to road crashes have become a matter of serious concern in both urban and rural areas. For enhancing safety on urban roads, several measures need to be undertaken. The key design principles and strategies in this context may be as under:

i) **Network Planning:** The road cross-section should accommodate the travel demand of all road users including pedestrians and cyclists. Retrofitting of existing roads would require giving attention to providing space for vulnerable road users and the design of facilities for pedestrians, thus to adhere to the universal accessibility principles. In this context, reference may be made to Chapter 2 on Planning and Development of Urban Roads and Streets, Chapter 5 on Pedestrian Facilities and Chapter 6 on Cycle Tracks.

ii) **Safer Vehicle Speeds:** Bring down speeds of motorized vehicles to safer levels. For this, a number of evidence-based traffic calming measures can be adopted. Can refer to IRC:99.

iii) **Promoting Public Transport:** There is now recognition in states to expand and strengthen the public transport system in bigger cities and towns. This step, in itself, would lead to enhanced safety by reducing the risk associated with travel by cars and motorized two-wheelers, apart from reducing congestion and pollution. Several cities have recently provided Metros and Bus Rapid Transit Systems.

iv) **Installation of Traffic Control Devices:** Traffic control devices such as road signs, pavement markings, hazard markers, delineators, crash barriers need to be installed on the urban roads network as per the guidelines given in various IRC codes and manuals. Brief explanation of these devices are given in succeeding paragraphs.

v) **Implementing Work Zone Traffic Management Plan:** The Work Zone Safety of road users and construction workers need to be ensured at all sites where work of construction or maintenance is executed. Brief details are given in this chapter.

16.2 Road Signs

16.2.1 *Function*

Road signs give information about the road conditions ahead, provide instructions to be followed at the major crossroads or junctions, warn or guide drivers, and ensure proper functioning of road traffic. The signs should:

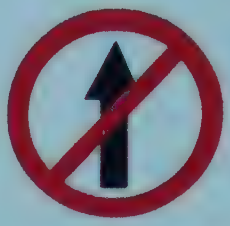
a) Fulfil a need;
b) Command attention;
c) Convey a clear, simple meaning;
d) Command respect from road users; and
e) Give adequate time for proper response.

Road signs should be so located that they are within the road user's line of sight. They should be appropriately positioned with respect to the location to which it applies as to provide adequate response time to road users.

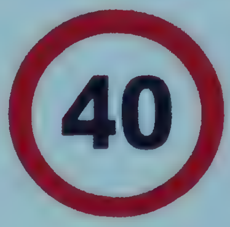
16.2.2 *Classification*

Road Signs are classified under the following three heads (For details refer IRC:67-2012):

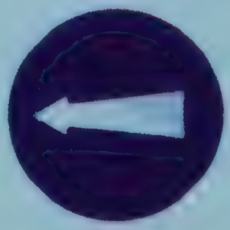
i) **Mandatory/Regulatory/Prohabitory Signs:** Regulatory signs indicate requirements, restrictions and prohibitions. These include signs, such as, STOP, GIVE WAY, Speed Limits, No Entry, etc which give notice of right of way, special obligations, prohibitions or restrictions with which the road users must comply. These are installed to give effect to a traffic regulation order or other statutory provision. Regulatory signs either give legal based instructions or indicate a prohibition. Signs giving legal instructions are generally circular with a red border and symbol in black on a white background. Mandatory signs have white colour sign on a blue background. They usually indicate something all drivers must do (e.g. keep left). The exceptions in shape are the octagonal red STOP sign and the triangular GIVE WAY sign. These two signs provide indication about the right of way to drivers. STOP sign should not be used at signalized intersections. At such intersections only the word 'STOP' is provided as marking on the pavement.



Prohibitory Regulation



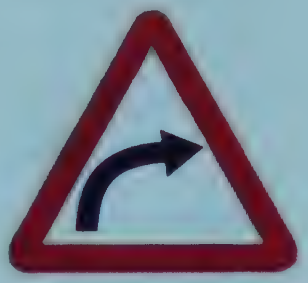
Operational Control



Compulsory Direction Control

ii) **Cautionary/Warning Signs**

Warning signs are used to caution and alert the road users of potential danger or existence of certain hazardous conditions either on or adjacent to the roadway so that they can take the desired action. These signs indicate a need for special caution by road users and may require a reduction in speed or some other manoeuvre. Some examples of these signs are Curve, Hairpin Bend, Narrow Bridge, Gap in Median, School Ahead etc. These are triangular in shape with red border and sign in black colour on a white background.



Cautionary/ Warning

iii) **Informatory/Guide Signs**

These signs are used to provide information and to guide road users along routes. The information could include names of places (recreational, tourist, cultural interest area signs and emergency management signs), sites, direction to the destinations, and distance to places, to make the travelling/driving easier, safer and pleasant. Guide signs are essential to direct road users to inform them of intersecting routes, to direct them to cities, towns, villages, or other important destinations within cities, and to forests, and historical sites. These are rectangular in shape having green/blue/ white background and sign in white/black in colour.

400m
Dhaula Kuan
Shankar Vihar
Gurgaon
Airport

16.2.3 *Placement with respect to Carriageway*

The signs shall be so placed that the drivers can see and recognize them easily and in time. Normally the signs shall be placed on the left hand side of the road. For two lane roads, the signs may be placed on the left side of the carriageway repeated on the other side of the carriageway if local conditions are such that the signs might not be seen in time by the drivers. For multilane divided roads, the signs may be placed on left side of each carriageway. In case of hill roads, the signs shall generally be installed on the valley side of the road, unless traffic and road conditions warrant these to be placed on the hill side. The placement of signs with respect to carriageway with required height and clearance is given in **Table 16.1** and **Fig. 16.1**.

Table 16.1 Height and Clearance required for Sign Placement

	Minimum (mm)	Desirable (mm)	Maximum (mm)
A	600	1000	2500
B	1000	2000	3000
C	300	600	1000
D	2000	2000	2500
E	2100	2100	2500
F	5500	6000	6500
G	750		
H			5000
I	5000	7000	9000
J	1800	2000	2500

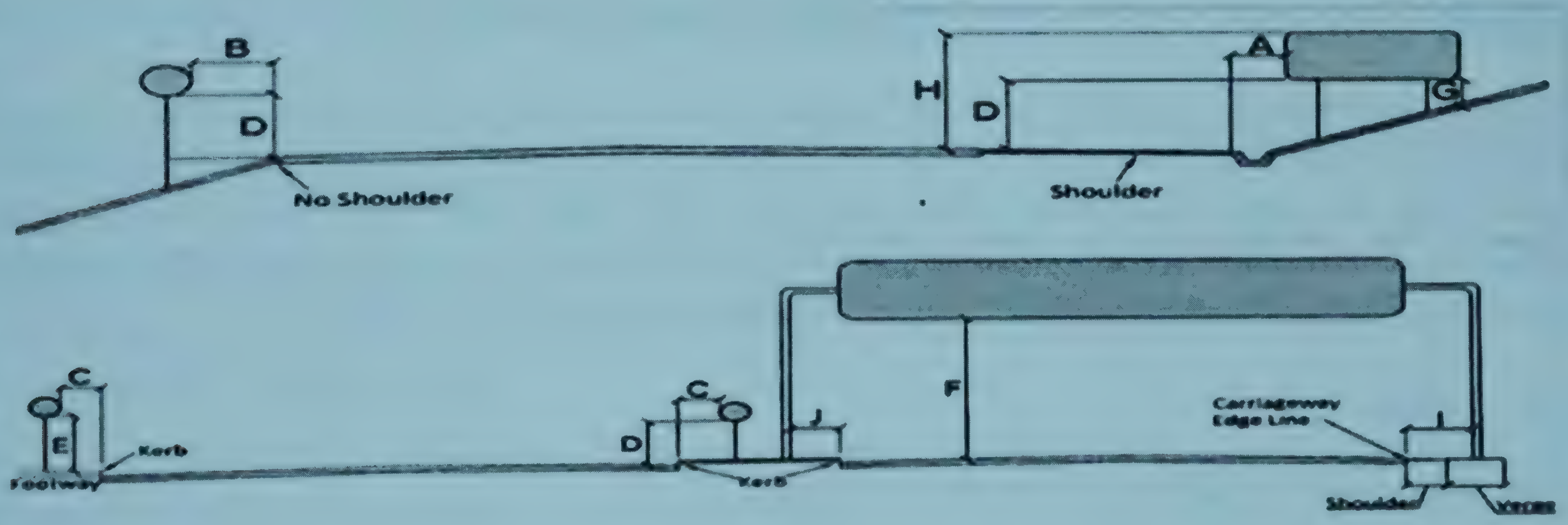


Fig. 16.1 Placement of Signs with respect to Carriageway

16.2.4 *Orientation*

- The signs shall be placed at right angles to the line of travel of the approaching traffic. Signs relating to parking, however, should be fixed at an angle (approximately) 15 degrees to the carriageway so as to give better visibility.
- Where light reflection from the sign face is encountered to such an extent as to reduce legibility, the sign should be turned slightly away from the road. On horizontal curves, the sign should not be fixed normal to the carriageway but the angle of placement should be determined with regard to the course of the approaching traffic.

- Sign faces are normally vertical, but on gradients it may be desirable to tilt a sign forward or backward from the vertical to make it normal to the line of sight and improve the viewing angle.

16.2.5 *Retro-reflective Sheeting*

The retro-reflective sheeting used on the signs shall consist of white or red sheeting having a smooth outer surface which has property of retro-reflection over its entire surface. For urban roads, Class B (Type III, Type IV) and Class C (Type VIII, Type IX, Type XI) are recommended. For details regarding the characteristics of each type, refer IRC:67.

16.2.6 *Symbols*

As far as possible, road signs should convey the message through symbols. For details refer to IRC:67.

16.3 Pavement Markings

16.3.1 *Function*

Pavement markings perform an important function of guiding and controlling traffic on roads. The markings serve as a psychological barrier and thus help to signify the delineation of traffic path and its lateral clearance from traffic hazards facilitating safe movement. Further, the markings channelize the pedestrians and cyclists movement into safe location and in effect, provide for an extension of the side walk/cycle track across the roadway. Road markings are, therefore, indispensable to ensure smooth and orderly flow of traffic and for promoting road safety particularly during night time. For details refer IRC:35.

Pavement markings are defined as lines, patterns, words except road signs which are applied or attached to the carriageway or kerbs or to objects within or adjacent to the carriageway for controlling, warning, guiding and informing the road users. Markings where used, shall be uniform in design, position and application so that they may be recognized and understood immediately. A uniform set of markings is applicable throughout the country.

16.3.2 *Material*

The materials commonly used for markings are:

- Hot applied thermoplastic compound
- Solvent borne and Waterborne Road Marking Paints
- Cold Applied Plastics
- Preformed Adhesive Tapes

'Specifications for Road and Bridge Works' of the Ministry of Road Transport and Highways (MoRTH) shall be referred for technical specifications of road marking materials.

i) **Thermoplastic Markings:** Thermoplastic is the most commonly used pavement marking material on roadways and is a mixture of plasticizer, glass beads and resins that serves to hold all of the other ingredients together. The thermoplastics hot applied in molten state adheres to pavement and get solidified immediately at the ambient temperature. Thermoplastic markings possess fast drying time and are highly durable. It has better retro reflective performance than that of ordinary road marking paint. The service life of one application of thermoplastic generally ranges from 2 to 3 years, depending on traffic volumes.

ii) **Solvent borne and Waterborne Road Marking Paints**

Road marking paints are oldest form of pavement marking materials. It can be used for longitudinal line application in temporary work zone markings and also for those marking which are required for a very short period and can be removed thereafter easily. The solvent-based and water-based are the two types of road marking paints. Water-based paint is environmentally friendly and is easier to handle compared to solvent-based paints and pose less safety hazards to workers. The road surface painted with water-based paints can be opened to traffic quicker than the road surface painted with solvent-based paints.

iii) **Cold Applied Plastics**

For coloured pavement marking, the cold applied plastic is a better choice than road marking paints and thermoplastic materials. Cold applied plastics are a good means to provide audible raised pavement marking for edge lines. Cold applied plastic is more durable than thermoplastic markings in retaining the original colour and luminance values. It can be applied to the surface in a variety of ways with a superior finishing and has no need of large application equipment and can be easily carried in a medium sized van and a trailer.

16.3.3 *Colour Pattern*

The general colour pattern followed for road marking and various background surfaces are given below:

White: Because of the visibility and good contrast against the road surface, the white colour should be widely used for road markings.

Yellow: The longitudinal marking in yellow colour should be used to convey message where it is not permitted to cross the markings. Yellow colour is also used to show parking restrictions and to impose other traffic control.

Blue: The blue colour should be used to indicate new and special markings which are not conventional. Blue is the colour of public transportation including three wheelers, scooters and rickshaws. The blue colour shall be used to indicate dedicated bus lanes in the Bus Rapid Transit (BRT) corridor on urban streets. In the bus lanes being marked across the intersection, the blue marking should be used to inform the road users that the lane is specifically meant for buses and other vehicles should not drive or stop in this lane.

Green: The green colour should be deployed to distinguish the bicycle and non-motorised transport facilities provided on the road. Green colour background should be marked at the intersection to give priority to the cyclists and pedestrians in crossing the road. When the motorized vehicles and non-motorized vehicles share the same carriageway, the green background lanes are preferred. When dedicated non-motorized lanes are built, a special green cycle boxes should also be used.

Red/Purple: Where multiple road users are sharing the road space on hazardous locations, the red color marking is primarily used to help people understand the danger. Red marking is recommended on hazardous intersections and also at places where pedestrians traffic conflict with the motorized traffic.

16.3.4 *Visibility*

Variety of factors influence the visibility distance of road marking. The visibility of the road marking gets enhanced when the line thickness is wider and with higher mark to gap ratio and also with higher coefficient of retro-reflective luminance. Therefore, larger pavement marking widths combined with higher coefficients of retro reflectivity are used to help drivers detect the lines according to design speed of roadway.

16.3.5 *Retro-reflectivity*

Retro reflection is accomplished in pavement-marking through the use of glass beads, partially embedded on the surface of the marking as binder material and also spread externally during application time. The quality of glass beads plays an important role in retro reflectivity of pavement-marking as the glass bead returns light from vehicle headlamp to a driver.

16.3.6 *Factors influencing Performance*

Many factors influence the performance of a given pavement marking material. The major factors can be grouped into three categories such as roadway surface; traffic and environment. These factors should be considered in the material selection process. Prior to marking, the pavement surface shall be clean and dry to achieve proper pavement marking performance. Materials being sensitive to the variables governing the application, warrant quality control during application.

16.3.7 *Classification*

Pavement Markings are broadly classified into following seven categories based on the placement of markings with regard to vehicular movement and also based on the function of the markings.

i) Longitudinal Marking (LM)
ii) Transverse Marking (TM)
iii) Hazard Marking (HM)
iv) Block Marking (BM)
v) Arrow Marking (AM)
vi) Directional Marking (DM)
vii) Facility Marking (FM)

i) Longitudinal Marking (LM)

The longitudinal marking are generally provided along the traffic movement. The broken lines, single/double continuous lines and continuity lines are classified under Longitudinal Marking and abbreviated as LM01, LM02, LM03, etc. As traffic moves forward, the broken longitudinal markings can be crossed, whereas continuous longitudinal markings shall not be crossed. The purpose of longitudinal marking is to navigate the driver for forward movements and to prohibit overtaking maneuver at hazardous locations. In a multi-lane road, the lane boundary established by longitudinal marking really guide to avoid side swipe and head on collision crashes. Refer **Figs. 16.2** and **16.3**.

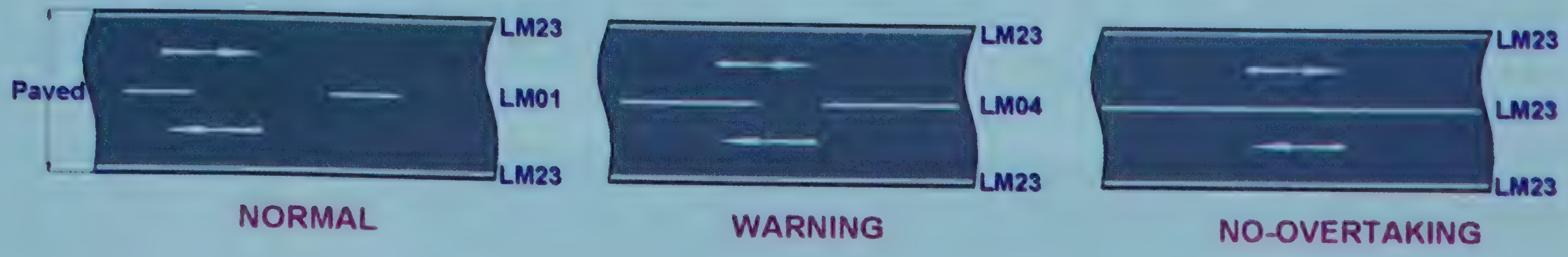

Paved
LM23
LM01
LM23
NORMAL
LM23
LM04
LM23
WARNING
LM23
LM23
LM23
NO-OVERTAKING

Fig. 16.2 Two Lane Bi-Directional Road

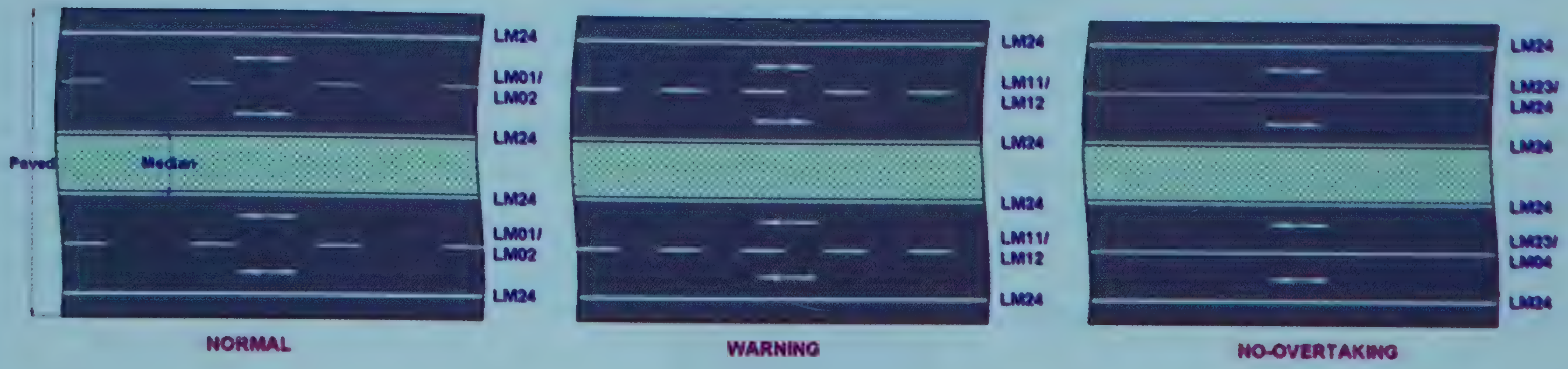

Paved
Median
LM24
LM01/
LM02
LM24
LM24
LM01/
LM02
LM24
NORMAL
LM24
LM11/
LM12
LM24
LM24
LM11/
LM12
LM24
WARNING
LM24
LM23/
LM24
LM24
LM24
LM23/
LM04
LM24
NO-OVERTAKING

Fig. 16.3 Lane Divided Carriageway

ii) Transverse Markings (TM)

The marking provided across the carriageway for traffic control with broken lines, single/double continuous lines such as Stop marking and Give way marking are classified under Transverse Marking(TM) and are abbreviated as TM01, TM02, TM03, etc. The transverse marking establishes the traffic control, lest it would lead to crashes, and therefore, its compliance is vital.

iii) Hazard Marking (HM)

The pavement marking that facilitates traffic merging/diverging, prohibiting to cross-over and to deflect the traffic ahead of hazardous situations, generally done with chevron and diagonal marking, hatch marking and prohibitory marking, are classified under Hazard Marking and are abbreviated as HM01, HM02, HM03, etc.

iv) Block Marking (BM)

The zebra crossing for pedestrians, triangular and chequered marking for speed breakers and Give Way symbol which are painted in blocks on carriageway are classified under Block Marking and are abbreviated as BM01, BM02, BM03 etc. The application of thermoplastic paint for block marking is generally different from longitudinal marking. The quality of block marking with adequate visibility is of utmost importance.

v) Arrow Marking (AM)

The arrows painted on carriageway are meant to give mandatory direction for driver and are classified under Arrow Marking and are abbreviated as AM01, AM02, and AM03, etc.

vi) Directional Marking (DM)

The word messages which are directional nature are classified under Directional Marking and are abbreviated as DM01, DM02, DM03 etc.

vii) Facility Marking (FM)

The marking for parking, the word messages for buses, cyclists and specially abled persons are classified under Facility Marking and are abbreviated as FM01, FM02, FM03, etc.

16.3.8 *Traffic Lane Lines*

The carriageway having two or more lanes in one direction are divided into separate lanes by traffic lane line marking for vehicles to move in proper lanes and to discourage the meandering tendency of the drivers, thereby promoting safety and ensuring smooth movement. At intersections and on approaches thereto, marking of traffic lanes eliminates confusion and facilitates through and turning movements. Traffic lanes should also be marked near pedestrian crossings and at other dangerous locations in congested area where the carriageway can accommodate more than one lane, and also on important one-way streets.

16.3.9 *No Overtaking Lines*

No overtaking zones shall be established on summit curves, horizontal curves and elsewhere on two and three lane highways where overtaking maneuvering must be prohibited because of restricted sight distances or other hazardous conditions. It is represented by solid central line.

16.3.10 *Warning Lines*

Warning lines are broken lines and are marked on horizontal and vertical curves where the visibility is greater than Minimum Visibility Distance (MVD), but less than the Warning Sight Distance (WSD) lines in order to make the broken lines look more conspicuous.

16.3.11 *Edge Lines*

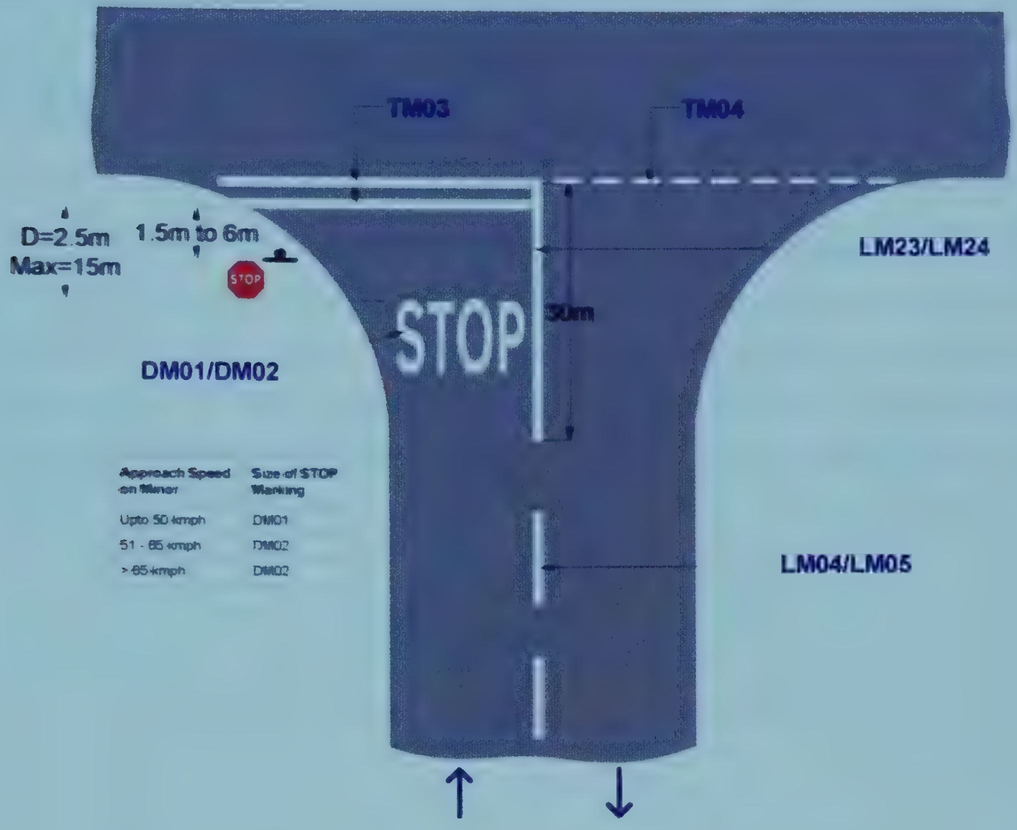
The border or edge lines are intended to indicate end of the carriageway and thus help to delineate the limits up to which driver can safely venture. This continuous guideline makes night driving comfortable especially, during inclement weather.

The pavement edge lines are desirable at the following locations:

- Where the shoulder is paved and is of similar texture and colour to the main carriageways
- In advance of and near narrow bridges and around sharp curves
- Where obstructions on the shoulder are close enough to constitute a hazard to the motorist
- On pavement width transitions
- On heavily trafficked two and three lane roads where head lamp dazzle is severe
- Along stretches which are prone to fog and mist.

16.3.12 *Stop Line Markings*

Stop line indicates the location on the ground beyond which the vehicles shouldn't proceed where it is laid, such as the vicinity of traffic signals, pedestrian zebra crossings and on minor road approaches merging with major roads. This marking is provided in conjugation with the stop sign on unsignalized intersections.


TM03
TM04
D=2.5m
Max=15m
1.5m to 6m
STOP
LM23/LM24
STOP
30m
DM01/DM02
LM04/LM05

Approach Speed on Minor	Size of STOP Marking
Upto 50 kmph	DM01
51 - 65 kmph	DM02
> 65 kmph	DM02

Fig. 16.4 Stop Line Markings with Stop Sign

16.3.13 *Give Way Markings*

The Give Way Markings consist of two broken lines laid side by side, it is coupled with the Give Way sign.

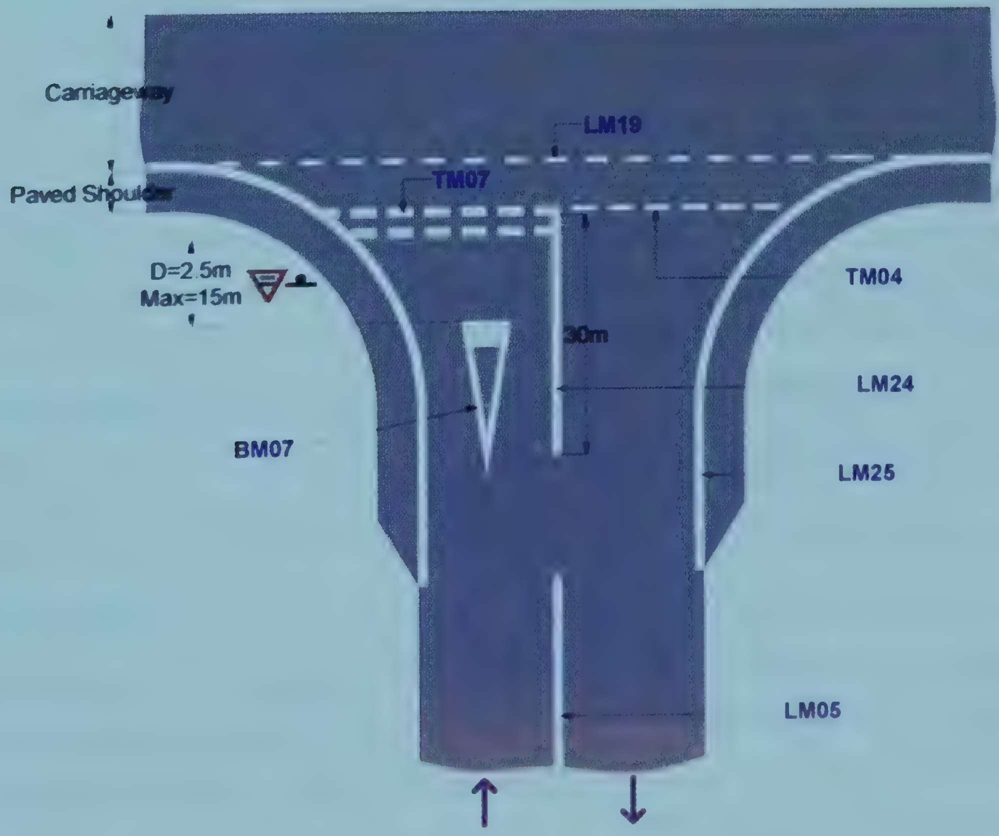

Carriageway
Paved Shoulder
LM19
TM07
D=2.5m
Max=15m
TM04
30m
LM24
BM07
LM25
LM05

Fig. 16.5 Give Way Marking with Give Way-Sign

16.4 Road Studs

16.4.1 *General*

Retro-reflective studs (**Fig. 16.6**) are used to supplement longitudinal/transverse reflectorized road markings, which would improve visibility in night time and adverse weather conditions. Road studs are also used across the carriageway to serve as Speed Arrestor coupled with eschewing warning through the creation of the rumbling sensation to the user. The performance of road studs depends upon the amount of light received from vehicle head lamps reflected back towards the source.

Studs shall be made of plastic material with reflectors for all type of roads. These reflectors should have abrasion resistant protective coating. The studs with shank or without shank can be bonded to road surface with suitable epoxy adhesive. Uni-directional road studs shall be used on one directional carriageway of undivided roads, one way street or slip roads. Bi-directional road studs shall be used for two directional roads to delineate the centre line and edge line.

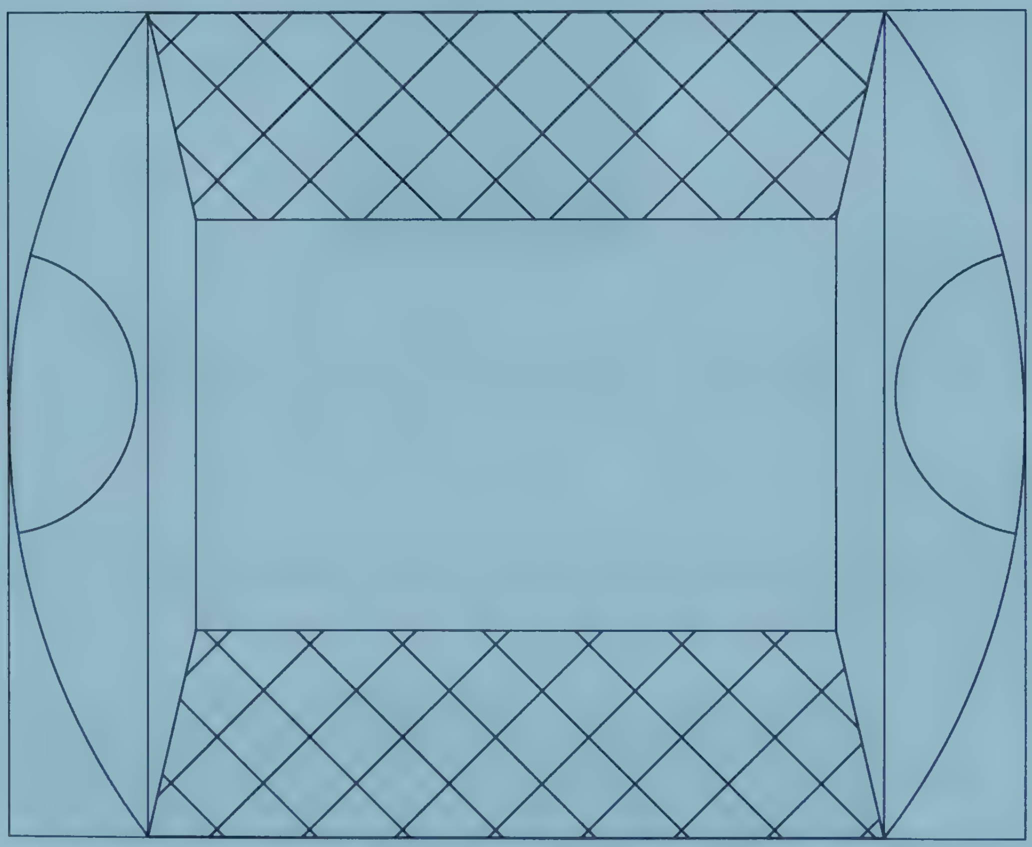


Fig. 16.6 Road Studs

16.4.2 *Colours for Road Studs*

The studs with different colours of reflectors such as white, red and yellow are used for highways. The usage of different colours of studs is as follows.

White Colour: White road studs are to indicate traffic lane line and centre of carriageway.

Red Colour: Red road studs are to be used to indicate a line which should not be crossed and mainly to delineate left hand edge of the running carriageway i.e. for road studs to be used on shoulder side edge line. The road studs shall be omitted or can be replaced with green colour where the facility for exiting traffic are provided from the main carriageway like entry to Truck Lay Bye/Bus Bay, 'Start of Service Road', etc.

Yellow Colour: Yellow road studs are to be again deployed to indicate a line which should not be crossed with the aim to delineate the right hand edge of the running carriageway in case of the multi-lane divided carriageways i.e. median side edge line.

Green Colour: Green road studs are to be employed to indicate crossable edge line like the lay byes and to show the boundary of acceleration or deceleration lane on left hand side of the carriageway in case of the multi-lane divided carriageways.

Uni-directional carriageways shall have one coloured face with the applicable colour given above, whereas the Bi-directional carriageways shall have two coloured faces which can be a combination of two colours such as Red-White bi-directional road studs or same colour on two faces like white –white bi-directional road studs or Yellow-Yellow bi-directional road studs.

16.4.3 *Solar Road Studs*

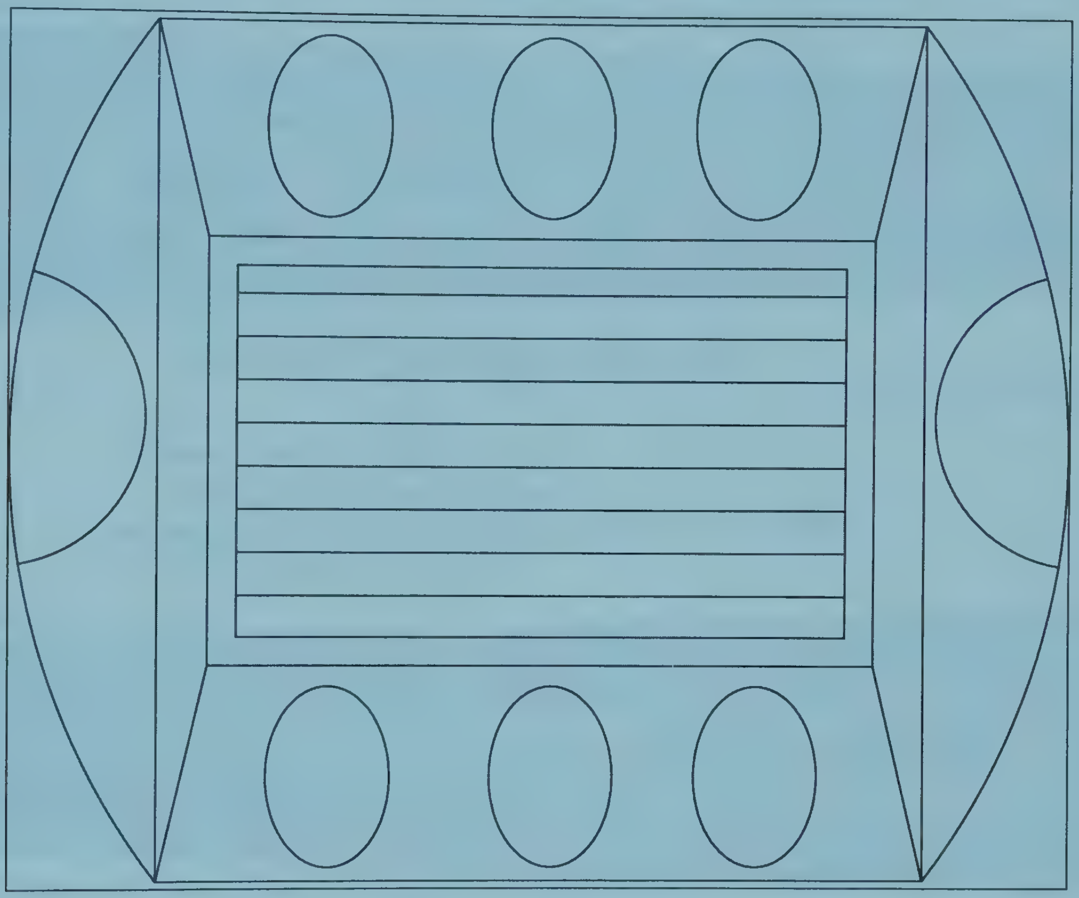
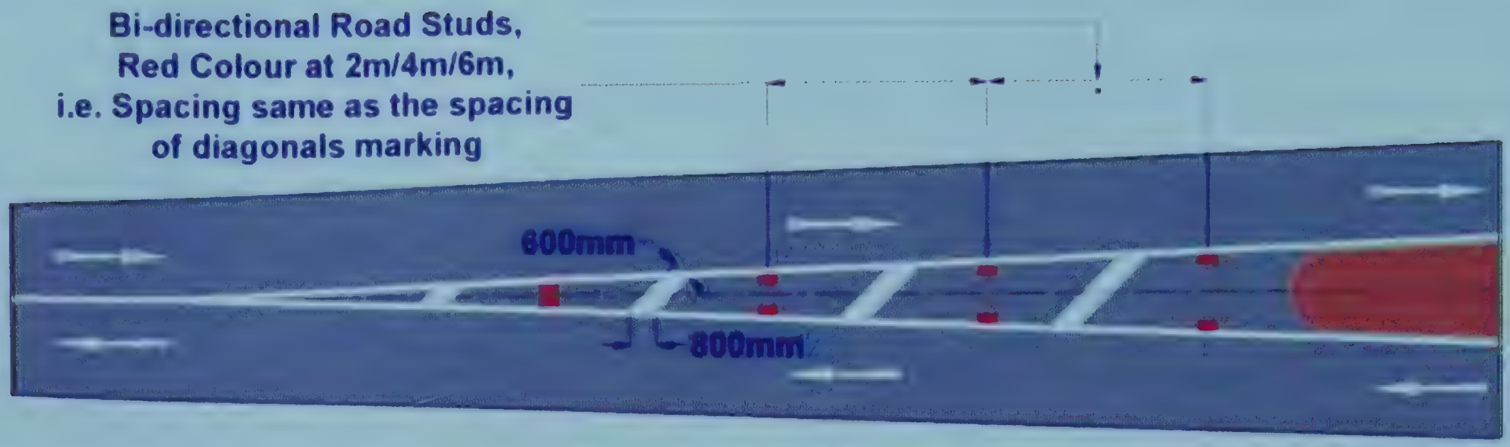


Fig. 16.7 Solar Studs

Solar Powered Road Markers (**Fig. 16.7**) are more effective which can immediately draw the attention of drivers and shall be provided at locations like approach to road crash prone locations and highly hazardous locations like bridge, toll plaza, sharp curves, pedestrian crossing, lane transition, speed humps, junctions, channelizes, construction sites, rail road crossings, accident prone locations, median opening and lane changing where performance of normal road studs are not that effective due to street lightings and other roadside activities.

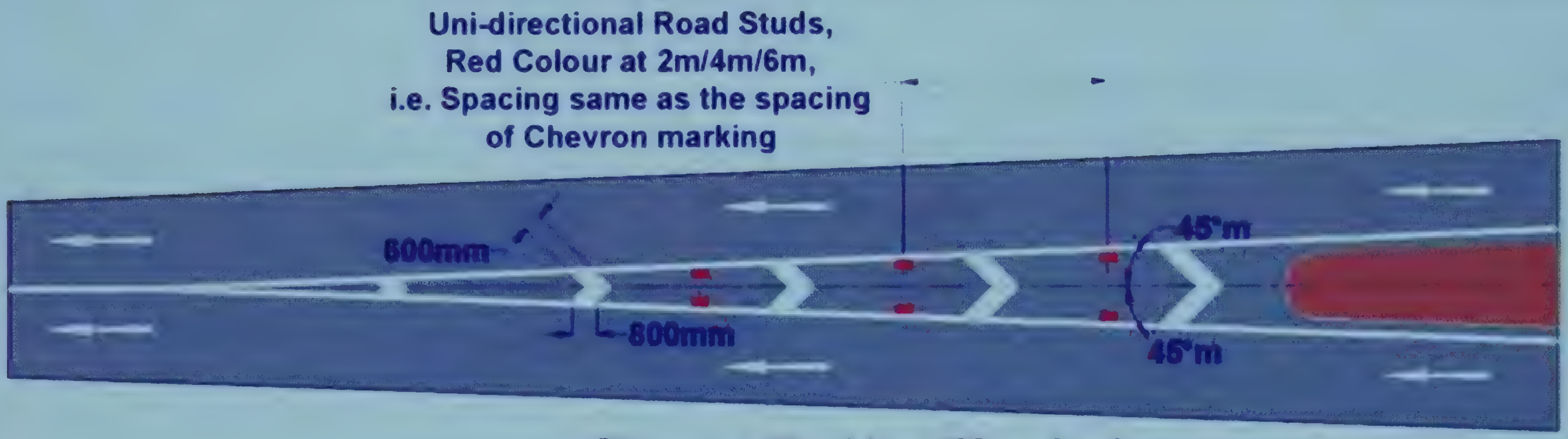
16.4.4 *Chevron Markings*

Chevron Markings are used to “channel” traffic flow, especially in town areas, as we ascend bridges and “flyovers” or “overhead bridges”. The Chevron Markings on Gorges are marked by “Red Color”. (**Fig. 16.8**)



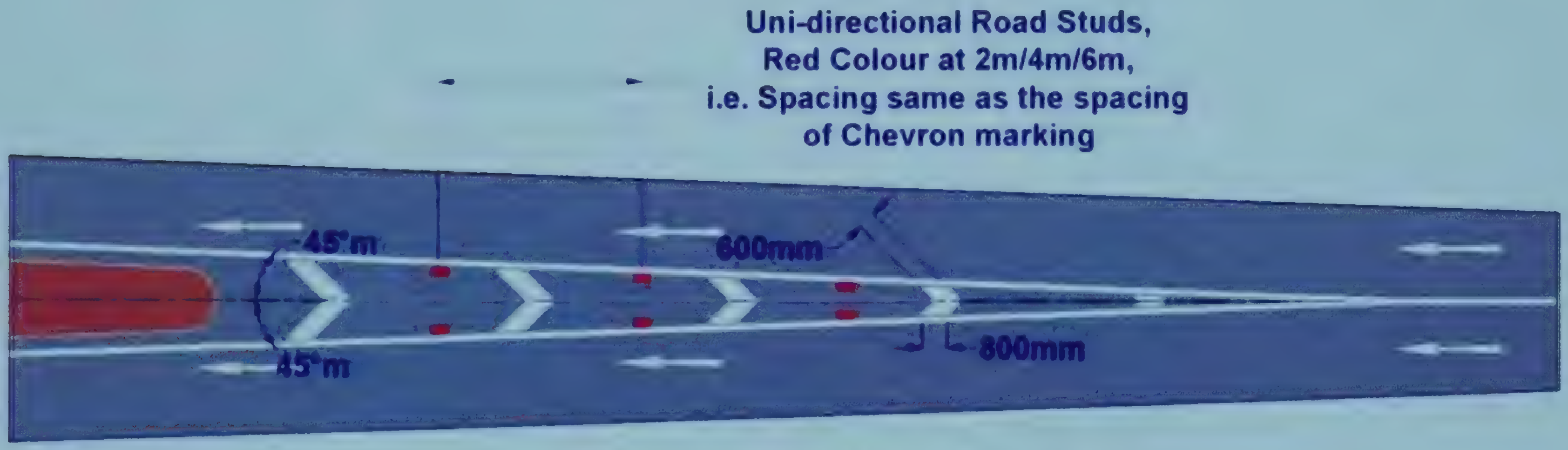
Bi-directional Road Studs,
Red Colour at 2m/4m/6m,
i.e. Spacing same as the spacing
of diagonals marking

Diagonal Marking



Uni-directional Road Studs,
Red Colour at 2m/4m/6m,
i.e. Spacing same as the spacing
of Chevron marking

Chevron Marking (Merging)



Uni-directional Road Studs,
Red Colour at 2m/4m/6m,
i.e. Spacing same as the spacing
of Chevron marking

Chevron Marking (Diverging)

Fig. 16.8 Road Studs for Diagonal & Chevron Marking

16.5 Crash Barriers

Crash Barriers (Traffic Safety Barriers) are provided on roads at hazardous locations such as:

- Sharp Curves
- Road side obstacles
- Approaches to bridges, grade separators
- High embankments
- Steep grades
- Dangerous Ditches

For details, refer IRC:119.

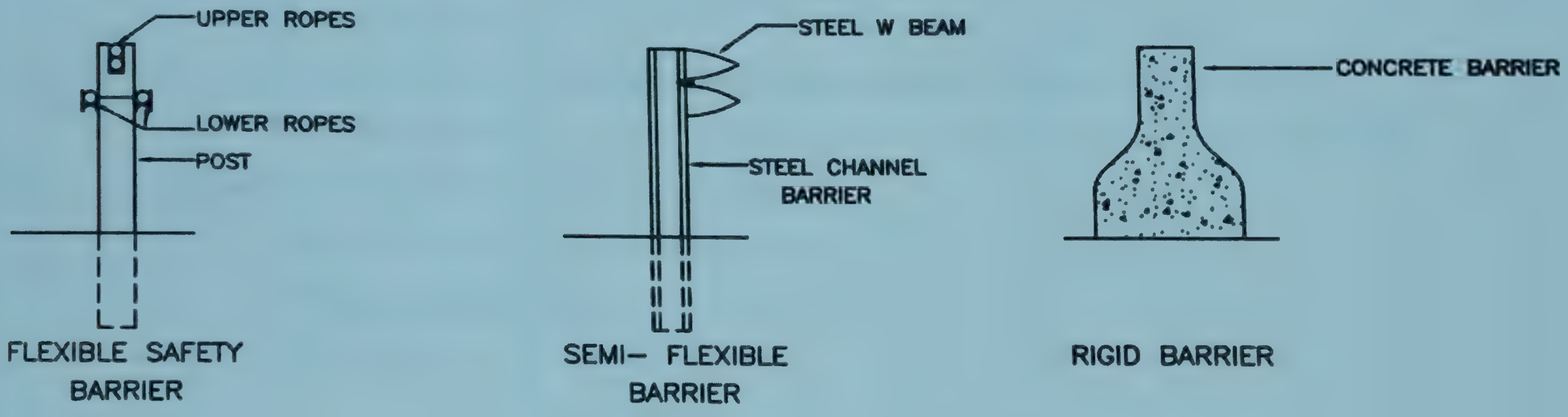
Barriers are placed:

- At the edge of carriageway (Roadside Barriers)
- In the median (Median Barriers)

Barriers are classified as:

- Flexible e.g. wire type barriers
- Semi-Rigid e.g. steel beam type barriers
- Rigid e.g. concrete type barriers

Main difference among these barriers is the amount of deflection that takes place when the barrier is hit by a vehicle (which loses or happens to lose control). See **Fig. 16.9** for the three types of barriers:



FLEXIBLE SAFETY BARRIER

SEMI– FLEXIBLE BARRIER

RIGID BARRIER

Fig. 16.9 Types of Safety Barriers

16.5.1 *Road Side Barriers*

i) Locations where generally provided

- Embankments with high fills and steep slopes
- Road side obstacle:- non-traversable hazards and fixed objects
- Approaches to bridge, grade-separators
- Footpaths, cycle tracks when close to the high speed highways
- Dangerous ditches
- Steep grades
- Hill roads

ii) Barriers for shielding roadside obstacles

a) Non-transverable hazard, if within clear zone

- Rough rocks cuts, large boulders
- Streams or water bodies more than 0.6m deep
- Shoulder drop-off with slope steeper than 1:1 and height more than 0.6m

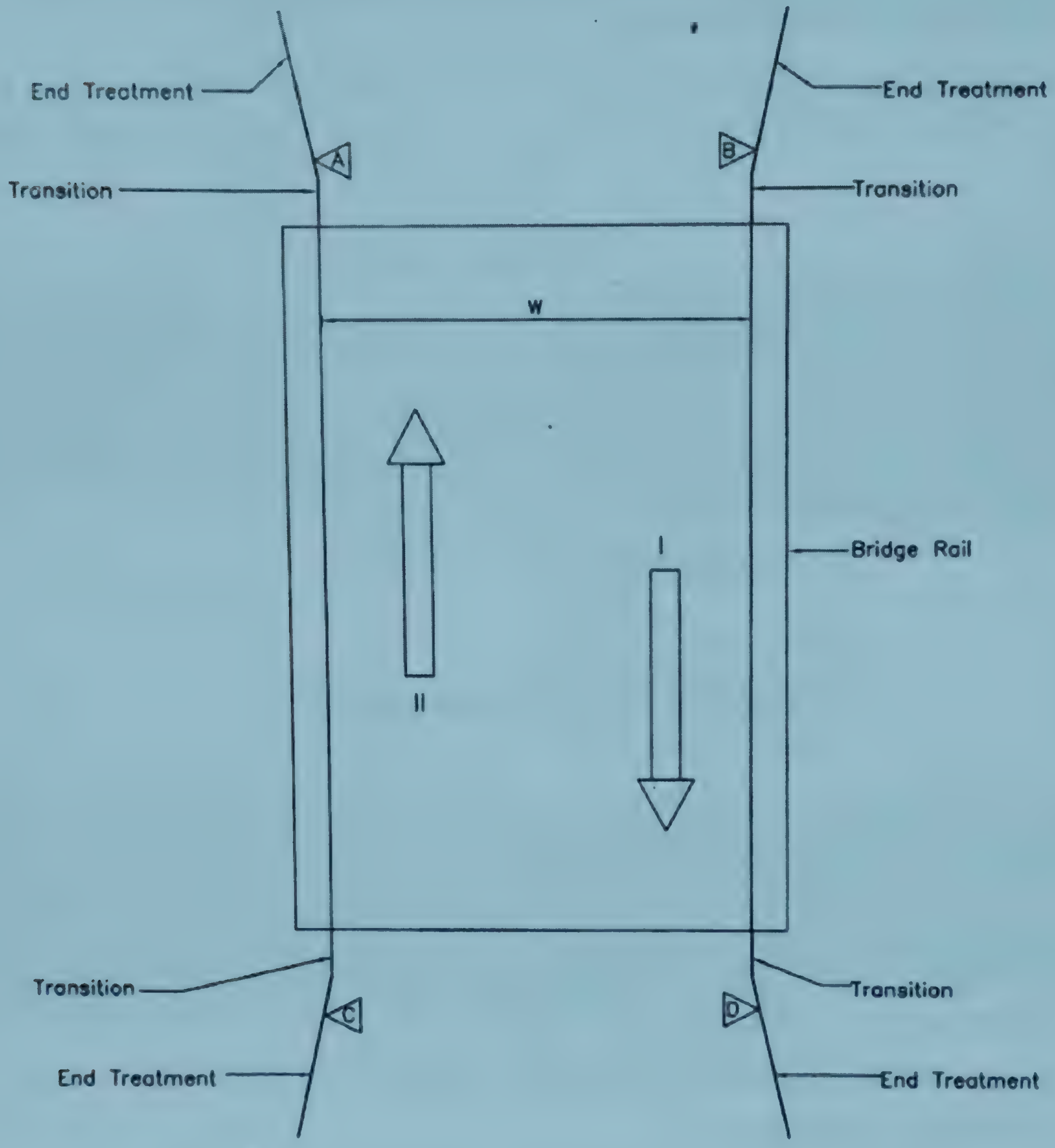
b) Fixed objects if within clear zone

- Signs, Signals, Luminaries support, wooden poles
- Bridge Piers, abutments at underpass
- Trees (girth more than 250mm)

Section of Barriers may start 25m in advance of the fixed object and may extend 25m beyond if sign support is not anchored and at least 8m when anchored. The off-set between the face of barrier and support should be minimum 0.6m.

iii) Bridge Rail Ends, Transitions and End Treatments

- **Fig. 16.10** gives the warrants for approach barrier to bridge, grade separators
- Transition section is required between approach barrier and railing
- Crash worthy end treatment is also warranted


End Treatment
End Treatment
A
B
Transition
Transition
W
Bridge Rail
I
II
Transition
Transition
C
D
End Treatment
End Treatment

Traffic Direction	Distance Between Bridge Rails –W (m)	Approach Barrier Required At
I And II	< 2 x Clear Zone Width	A,B,C,D
I And II	> 2 x Clear Zone Width	C,B
II Only	All Widths	C,D
I Only	All Widths	A,B

Fig. 16.10 Bridge Approach Barrier Criteria

iv) Sharp Curves, Steep Grades

On sharp curves and fixed objects like piers, abutments at underpasses, provision of W-Beam safety barriers would protect the vehicles from running off the road or colliding against the fixed objects.

On sharp curves, barriers may extend 100m beyond the beginning and end of curve

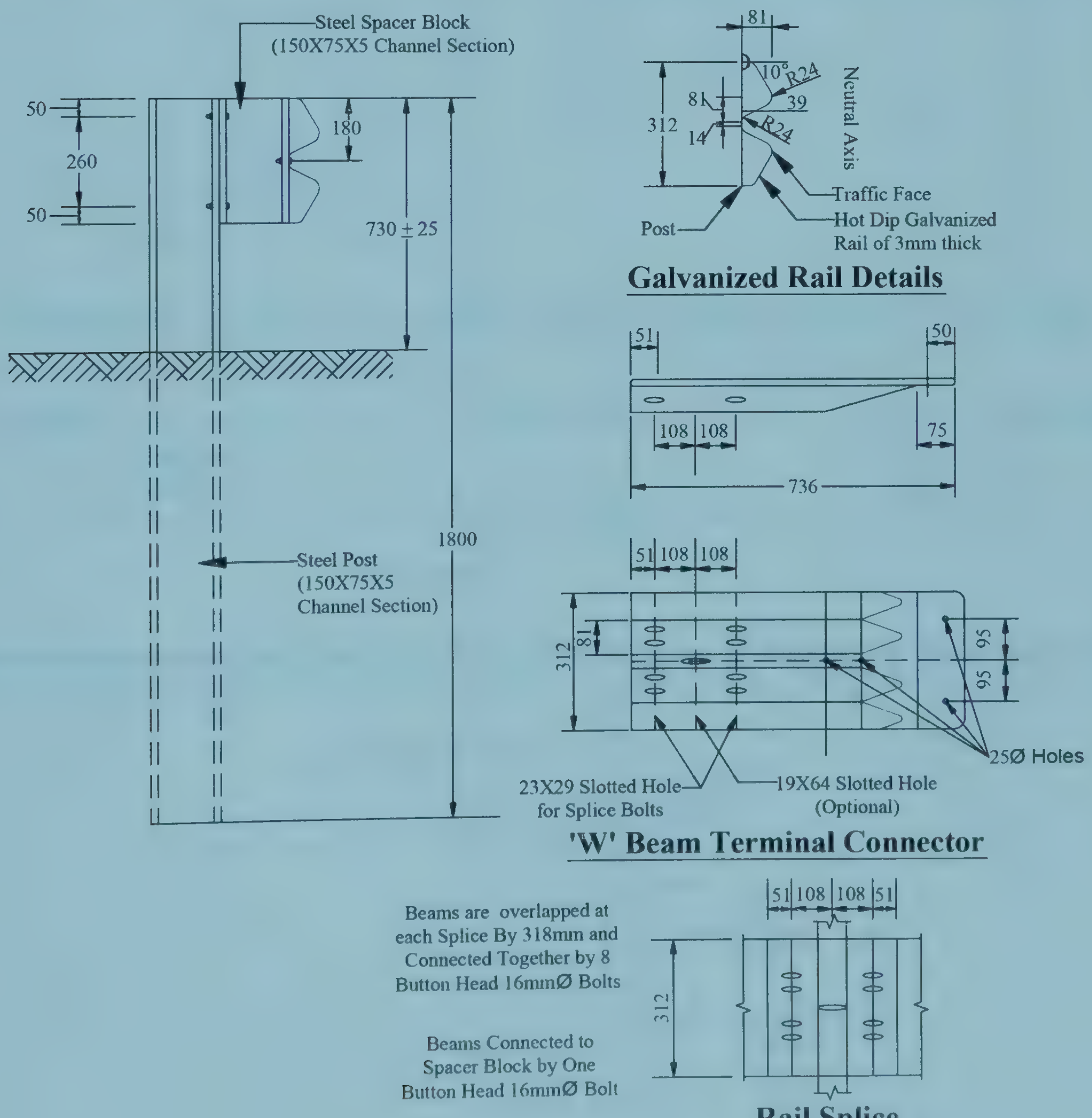
On piers, abutments, the length may be sufficient enough to protect these objects

v) Selection Guidelines for Roadside Barriers

- Appropriate Barrier :- provides degree of shielding required at lowest cost
- Important Parameters are
  - ➢ Performance Capability – Crash testing, accident experience
  - ➢ Deflection characteristics-
- Large distance between barrier and object :- Flexible barrier
- Small distance between barrier and object :- Semi rigid or Rigid
- Field Experience :- Maintain impact performance and repair cost data

vi) Most common Roadside Barriers are

- W-Beam steel barrier – **Fig. 16.11**
- Thrie beam steel barrier – **Fig. 16.12**
- Wire rope barrier – **Fig. 16.13**

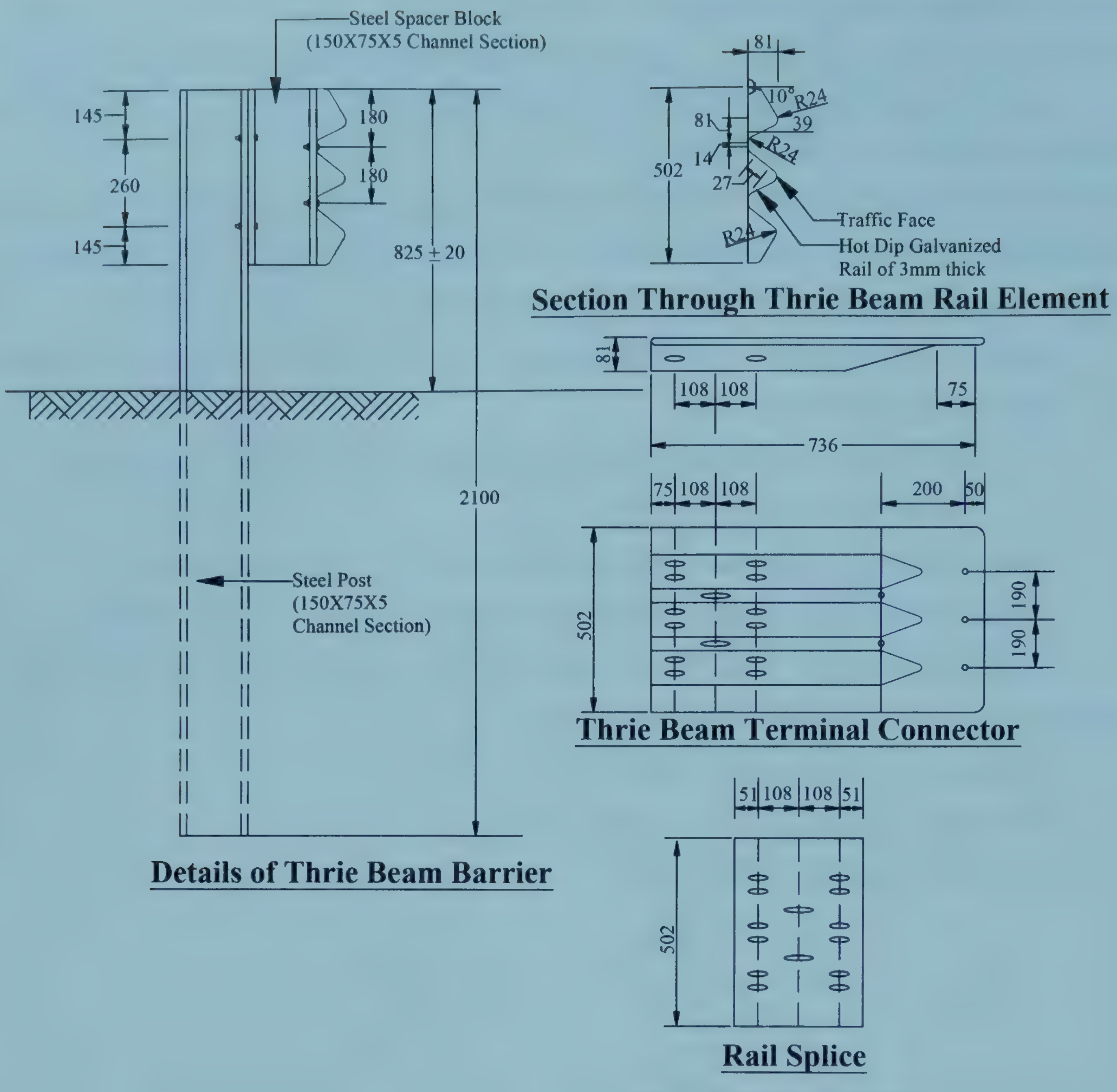

Steel Spacer Block
(150X75X5 Channel Section)
50
260
50
180
730 ± 25
1800
Steel Post
(150X75X5
Channel Section)
81
10°
R24
39
8
312
14
R24
Neutral Axis
Post
Traffic Face
Hot Dip Galvanized
Rail of 3mm thick
Galvanized Rail Details
51
50
108
108
75
736
51
108
108
312
81
95
95
25Ø Holes
23X29 Slotted Hole
for Splice Bolts
19X64 Slotted Hole
(Optional)
'W' Beam Terminal Connector
51
108
108
51
312
Rail Splice

Beams are overlapped at each Splice By 318mm and Connected Together by 8 Button Head 16mmØ Bolts

Beams Connected to Spacer Block by One Button Head 16mmØ Bolt

Note : All Dimensions in Millimeters

Fig. 16.11 Typical Details of 'W' Structural Elements


Steel Spacer Block
(150X75X5 Channel Section)
145
260
145
180
180
825 ± 20
2100
Steel Post
(150X75X5
Channel Section)
Details of Thrie Beam Barrier
81
10°
R24
39
81
14
R24
502
27
Traffic Face
Hot Dip Galvanized
Rail of 3mm thick
R24
Section Through Thrie Beam Rail Element
81
108
108
75
736
75
108
108
200
50
502
190
190
Thrie Beam Terminal Connector
51
108
108
51
502
Rail Splice

Note : All Dimensions in Millimeters

Fig. 16.12 Typical Details of Thrie Beam Structural Elements

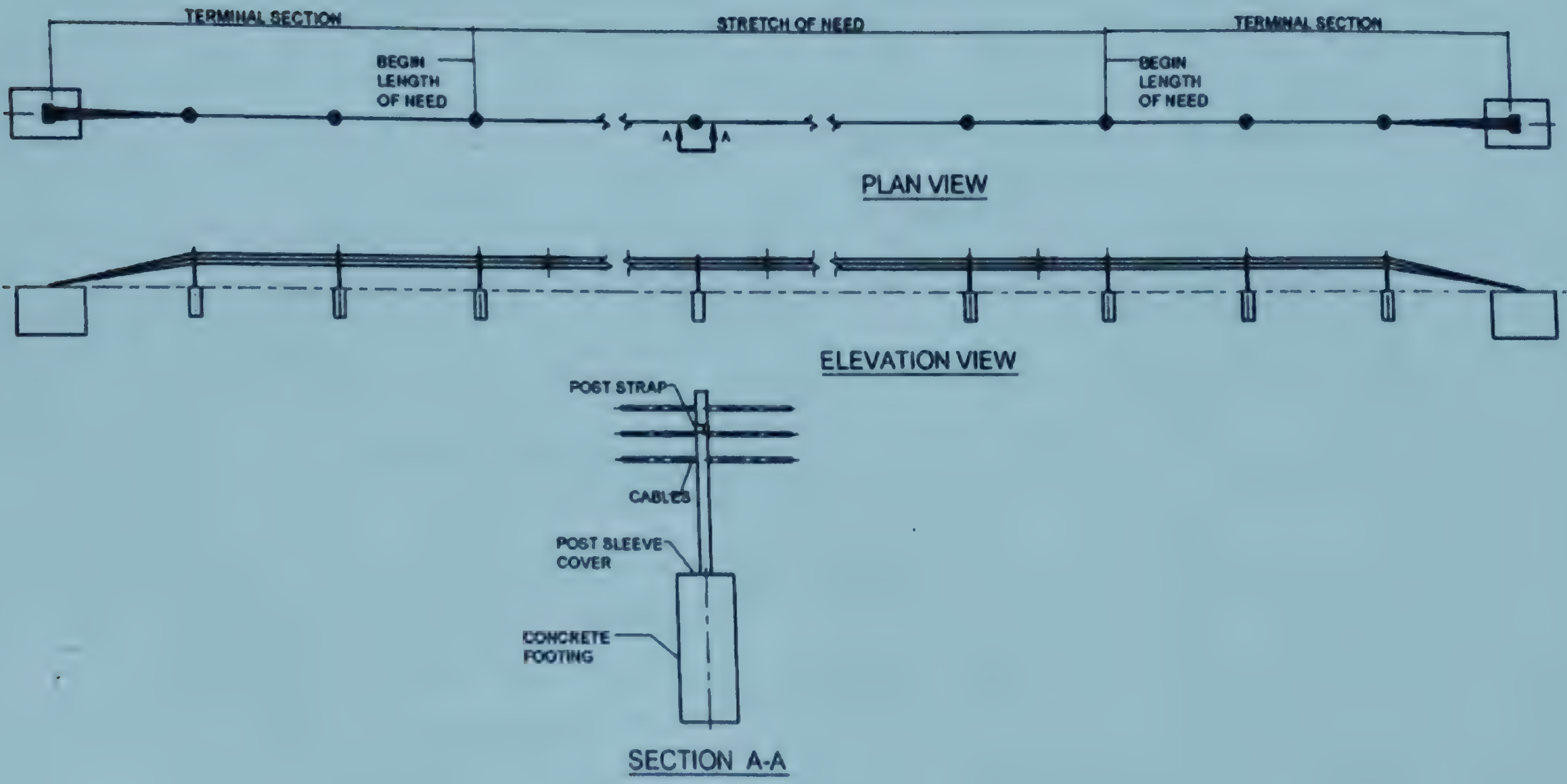

TERMINAL SECTION
STRETCH OF NEED
TERMINAL SECTION
BEGIN LENGTH OF NEED
BEGIN LENGTH OF NEED
A
A
PLAN VIEW
ELEVATION VIEW
POST STRAP
CABLES
POST SLEEVE COVER
CONCRETE FOOTING
SECTION A-A

Fig. 16.13 Typical details of Wire Rope Safety Barrier

16.5.2 *Median Barriers*

i) Warrants

- Barriers provided in the medians are called median barriers
- Protect traffic on both carriageways, especially with narrow medians
  - Prevent head on collisions caused by out - of – control vehicles
  - Shield fixed objects on medians

ii) Types of Median Barriers

- Blocked-out W beam type steel barriers – **Fig. 16.14**
- Blocked-out Thrie beam type steel barriers – **Fig. 16.15**
- Wire Rope Barrier – **Fig. 16.16**
- Median Wire Road Safety Barrier – **Fig. 16.17**
- Concrete Barrier – **Fig. 16.18**

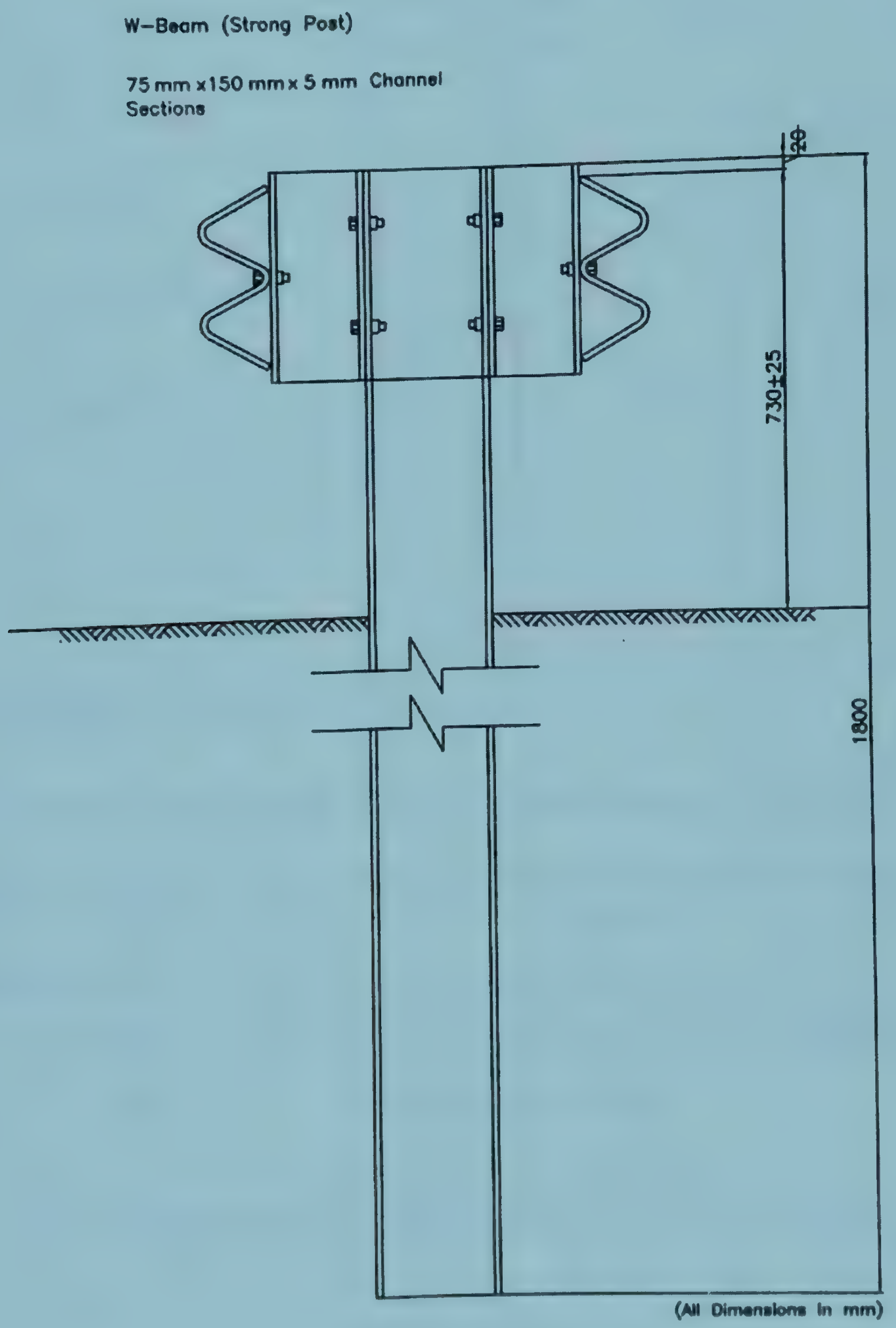

W–Beam (Strong Post)
75 mm x150 mm x 5 mm Channel Sections
20
730±25
1800
(All Dimensions in mm)

Fig. 16.14 Typical details of W Beam Median Barrier

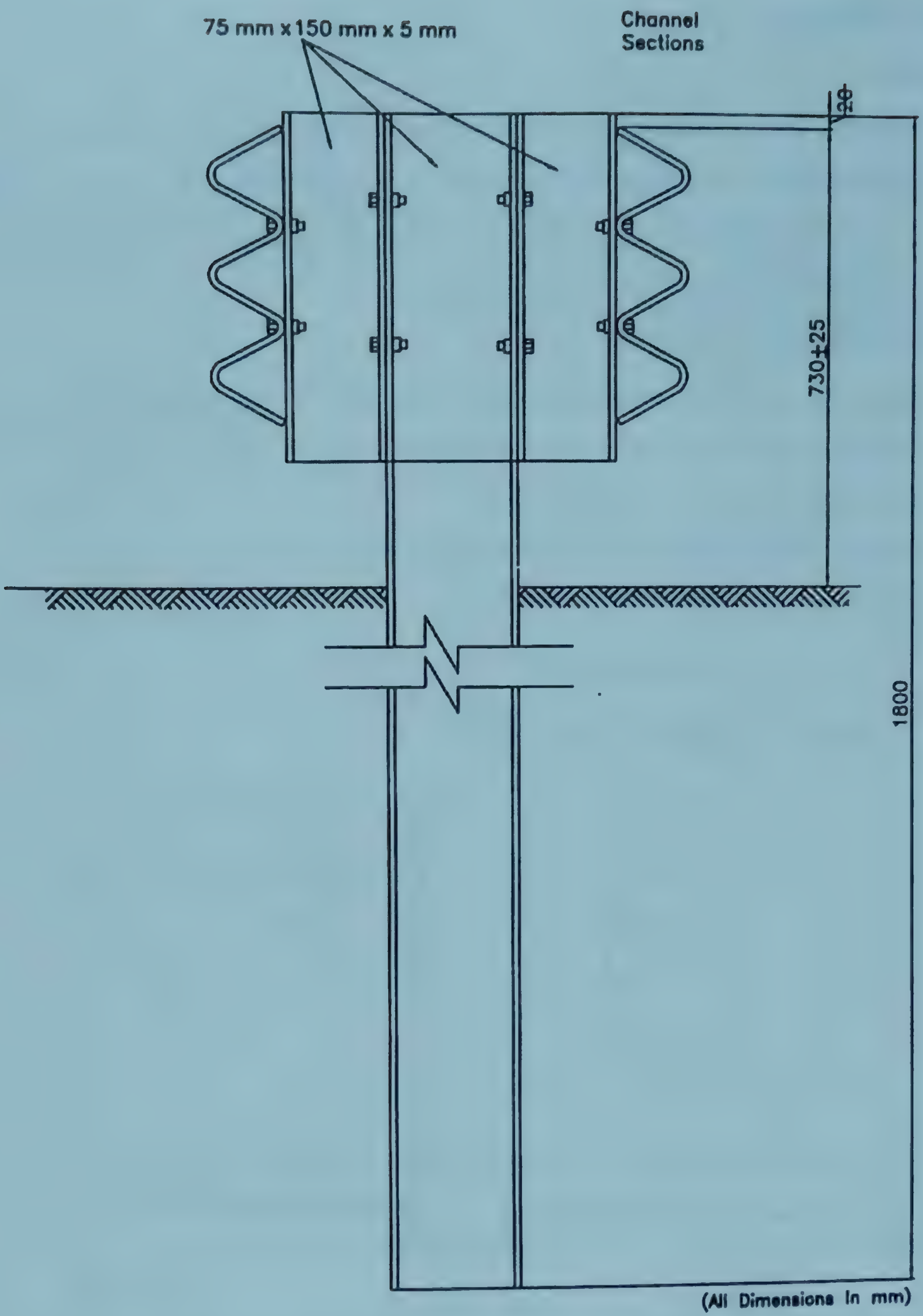

75 mm x 150 mm x 5 mm
Channel Sections
20
730±25
1800
(All Dimensions In mm)

Fig. 16.15 Typical Details of Thrie Beam Median Barrier

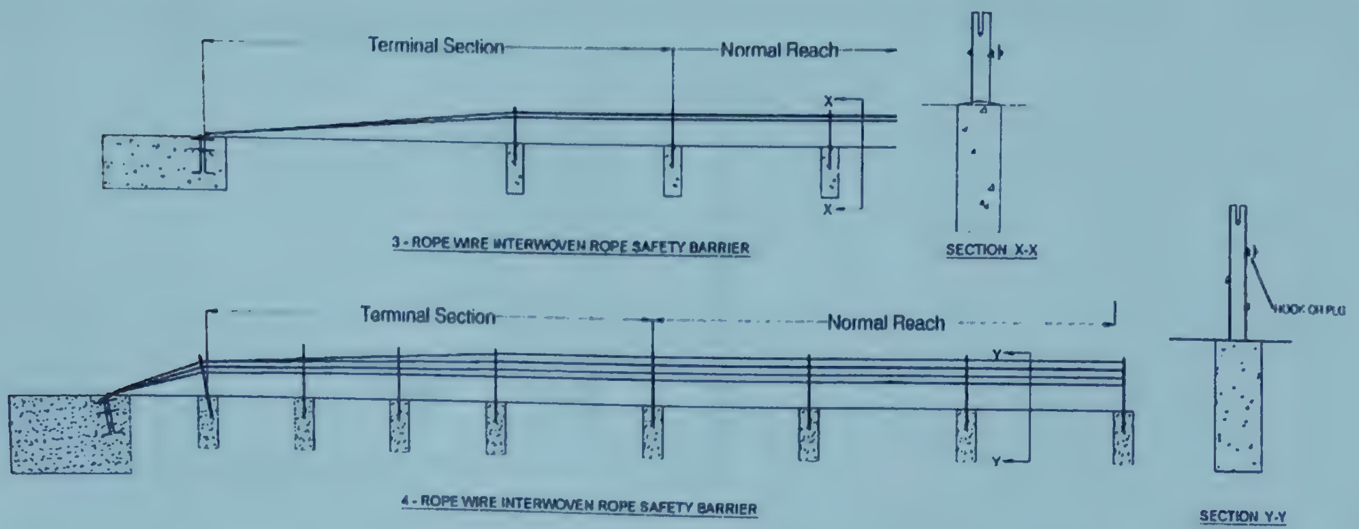

Terminal Section
Normal Reach
X
X
3 - ROPE WIRE INTERWOVEN ROPE SAFETY BARRIER
SECTION X-X
Terminal Section
Normal Reach
Y
Y
HOOK ON PLG
4 - ROPE WIRE INTERWOVEN ROPE SAFETY BARRIER
SECTION Y-Y

Fig. 16.16 Typical Details of Interwoven Wire Rope Safety Barrier

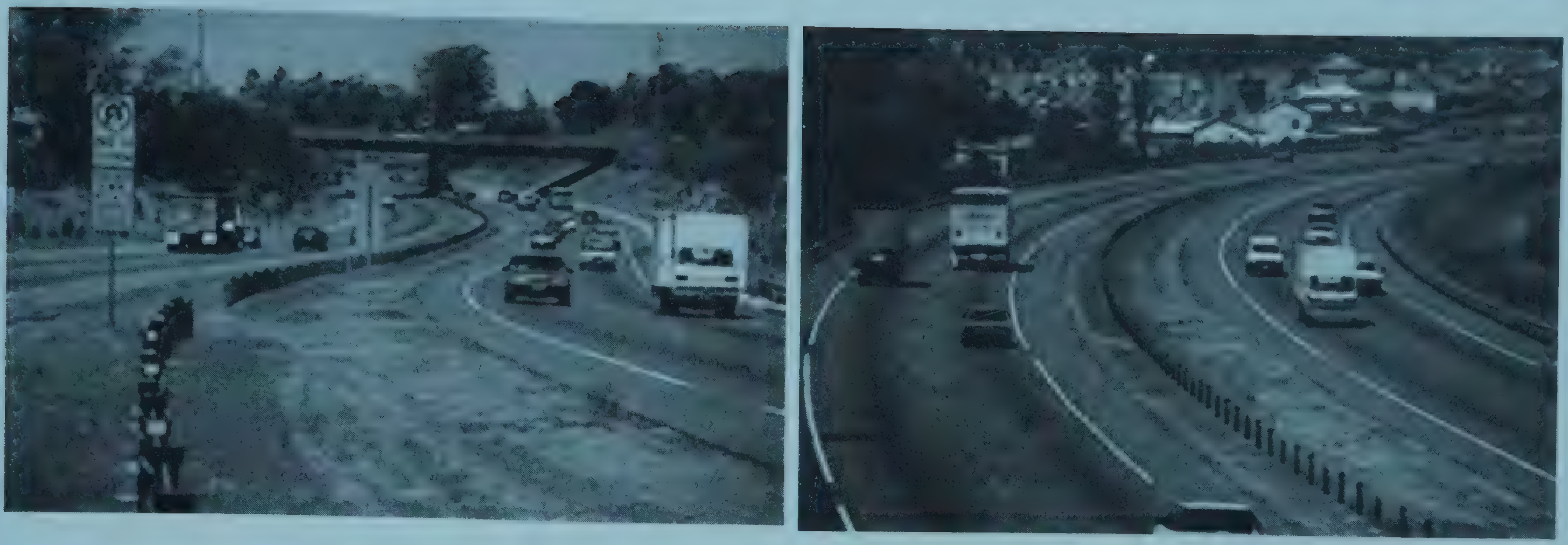


Fig. 16.17 Median Wire Road Safety Barrier

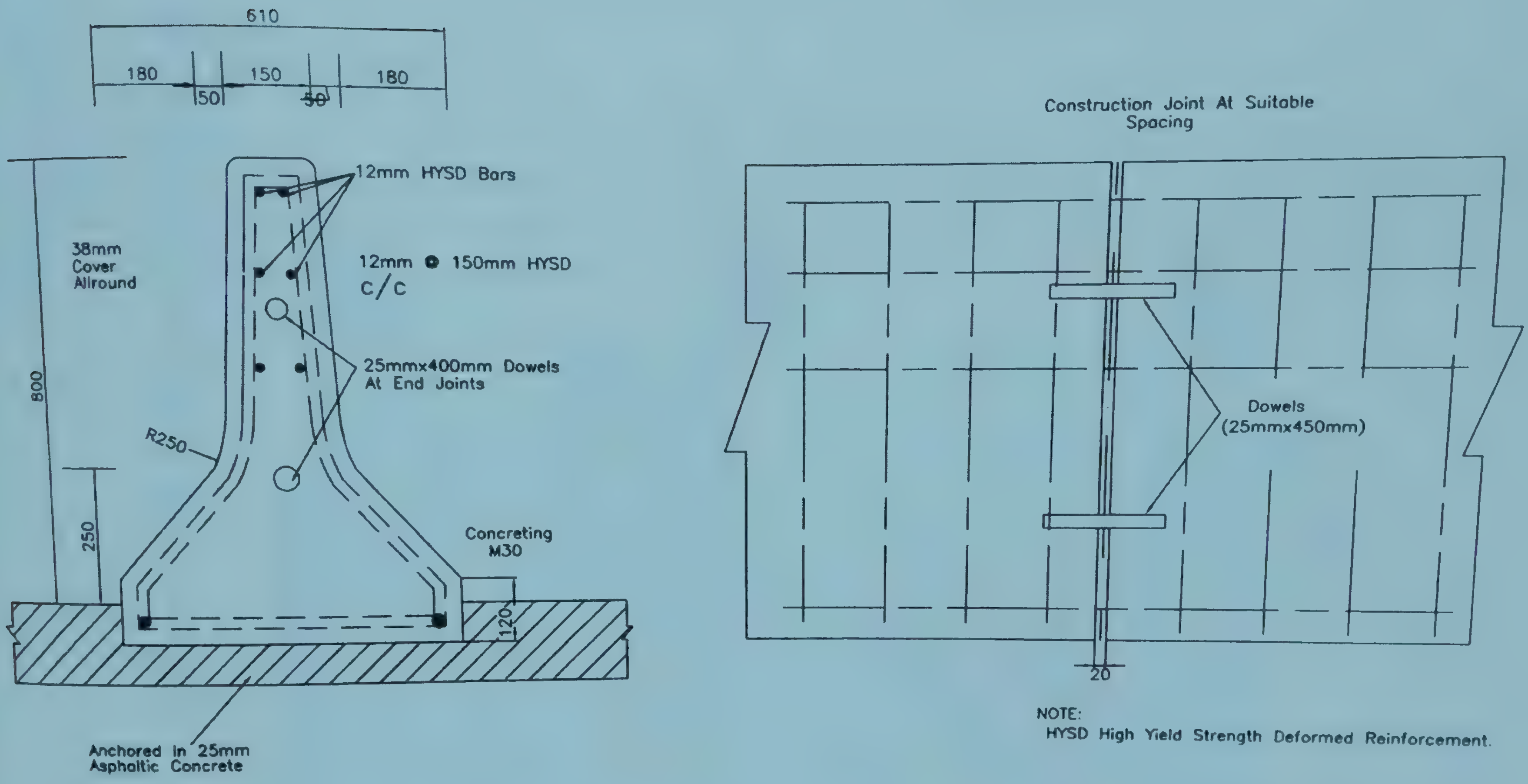
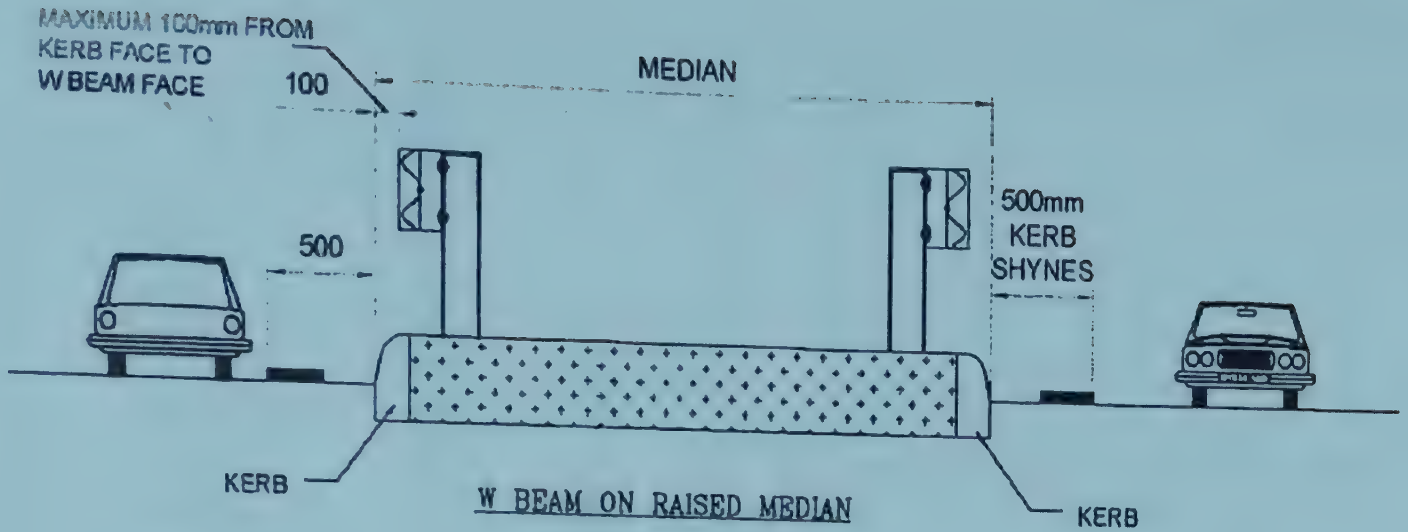

610
180
150
180
50
50
12mm HYSD Bars
38mm Cover Allround
12mm @ 150mm HYSD c/c
800
25mmx400mm Dowels At End Joints
R250
250
Concreting M30
120
Anchored in 25mm Asphaltic Concrete
Construction Joint At Suitable Spacing
Dowels (25mmx450mm)
20
NOTE:
HYSD High Yield Strength Deformed Reinforcement.

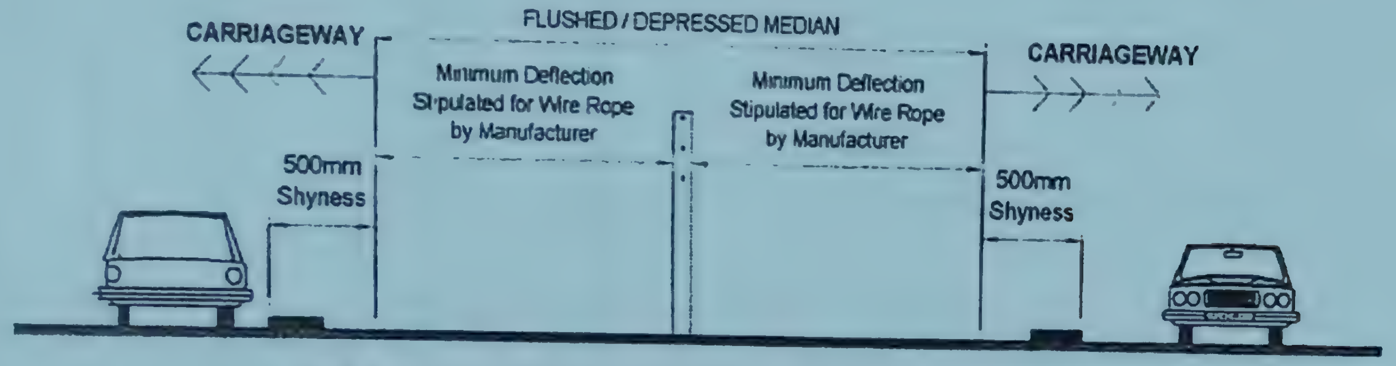
Fig. 16.18 Road Side/Median Barrier Cast-In-Situ Design

iii) Lateral Clearance

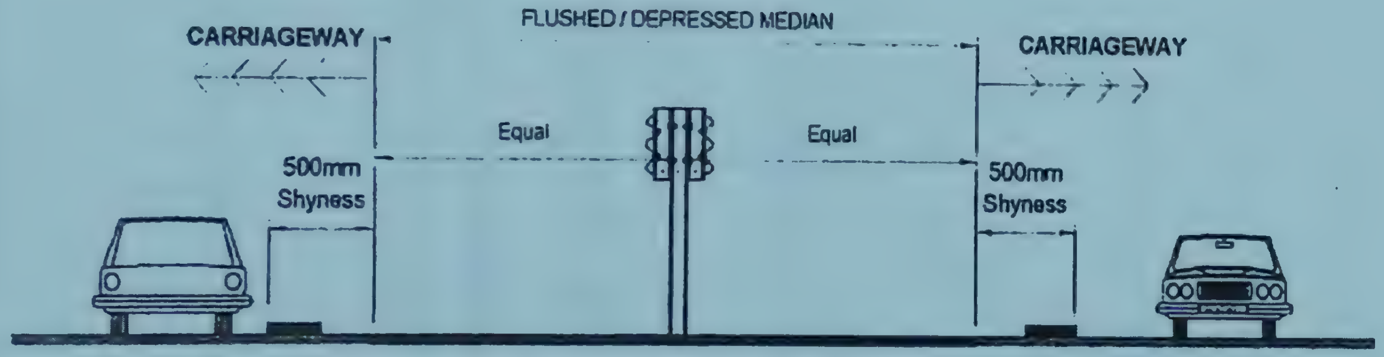
Fig. 16.19 gives the lateral clearance to be maintained in different site conditions.


MAXIMUM 100mm FROM
KERB FACE TO
W BEAM FACE
100
MEDIAN
500
500mm
KERB
SHYNES
KERB
KERB

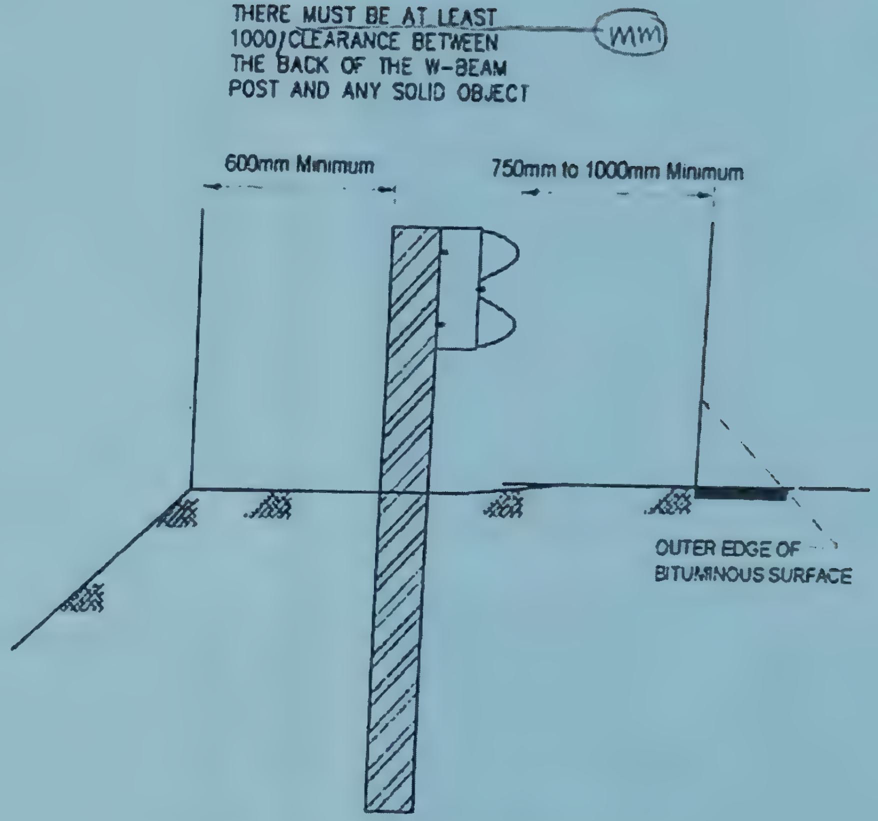
W BEAM ON RAISED MEDIAN


CARRIAGEWAY
FLUSHED / DEPRESSED MEDIAN
CARRIAGEWAY
Minimum Deflection
Stipulated for Wire Rope
by Manufacturer
Minimum Deflection
Stipulated for Wire Rope
by Manufacturer
500mm
Shyness
500mm
Shyness

WIRE ROPE AT THE CENTER OF FLUSHED / DEPRESSED MEDIAN


CARRIAGEWAY
FLUSHED / DEPRESSED MEDIAN
CARRIAGEWAY
Equal
Equal
500mm
Shyness
500mm
Shyness

W-BEAM AT THE CENTER OF FLUSHED / DEPRESSED MEDIAN


THERE MUST BE AT LEAST
1000 CLEARANCE BETWEEN
THE BACK OF THE W-BEAM
POST AND ANY SOLID OBJECT
MM
600mm Minimum
750mm to 1000mm Minimum
OUTER EDGE OF
BITUMINOUS SURFACE

W-BEAM ON SHOULDER / EMBANKMENT SIDE

Fig. 16.19 Lateral Clearance for Different Barriers

v) **Selection Guidelines**

- Performance requirements at minimum total cost
- Most situations : Standard Barrier
- For locations with poor geometrics and heavy trucks : Higher Performance level needed
- Narrow Medians : Rigid Barrier
- Wide flat median: Flexible and semi rigid in center are suitable
- Document field experience

Other General Recommendations

- Raised kerb or drains should not be provided between the carriageway and the barriers
- Avoid kerbed and raised median in dual carriageway as a good practice
- Attend to routine maintenance: occasional cleaning, painting
- Repairs, replacements equal to collision as per needs

16.6 Crash Cushions

Crash cushions are constructed of multiple segments, which crumple into each other when collided with to absorb the impact. Their main benefit is in their reusability; these attenuators can automatically return to their original position after a crash. An illustrative example is shown in **Fig. 16.20** in the form of sand-filled plastic barrels.

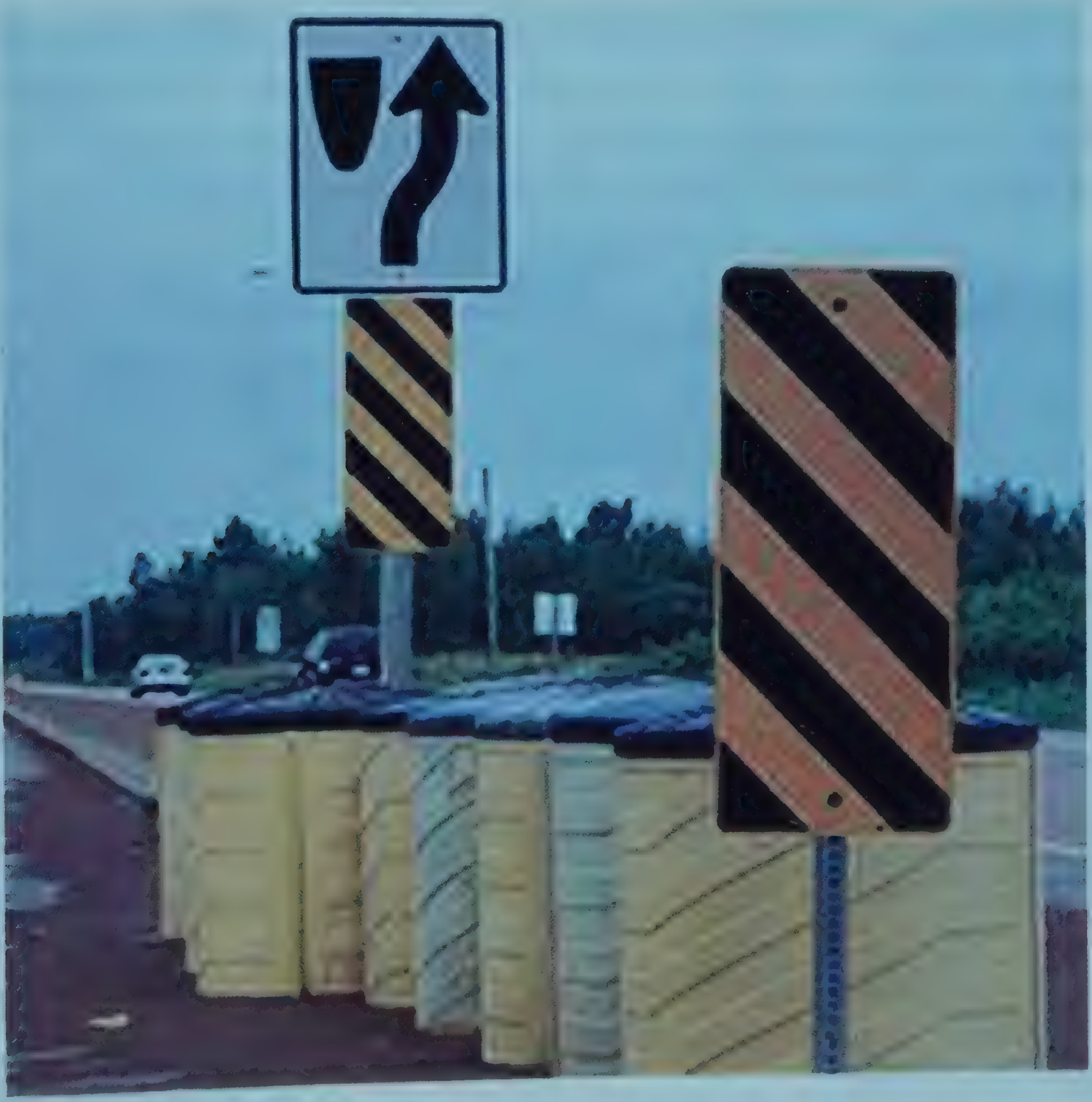


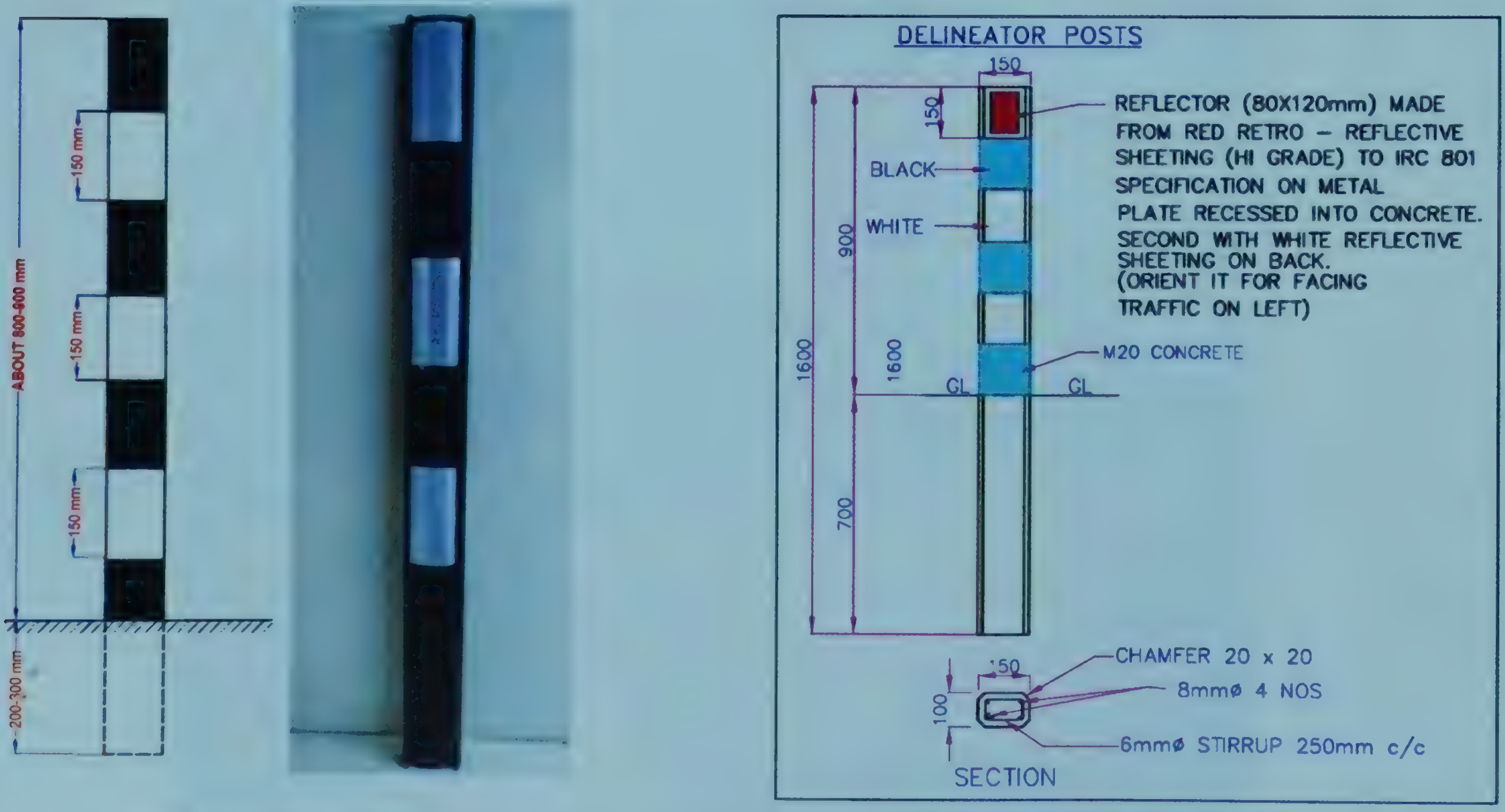
Fig. 16.20 Crash Cushions: Sand-filled Barrels

16.7 Delineators

Delineators provide visual assistance to drivers about alignment of road ahead, especially at night. Delineators are particularly effective in the case of complex locations involving changes in horizontal/vertical geometry, and during severe weather conditions such as heavy rain, fog or snow. Normally, reflectors are used on the delineators for better night time visibility. Delineators are basically driving aids and should not be regarded as a substitute for warning signs, road markings, or barriers for out-of-control vehicles. There are three types: Roadway Indicators, Hazard Markers and Object Markers.

16.7.1 *Roadway Indicators*

- Roadway indicators should be in the form of guide-posts made of metal, concrete, timber, cut stone, plastic or other suitable material depending on availability and cost.
- Iron tubes, concrete or plastic pipes, wooden posts, steel channel sections etc. can be conveniently adopted for the purpose.
- Plastic posts have the advantage of being safer for out-of-control vehicles while concrete pipes would be less prone to vandalism or theft.
- The post may have a circular, rectangular or triangular cross-section. However, the side facing the traffic should not be less than 10cm wide.
- Roadway delineator posts should be about 80-100cm high and painted alternately black and white in 15cm wide stripes.
- For improved visibility at night and at locations where visibility is poor due to fog etc., the delineator posts should be of reflectorised type, fitted with white colored rectangular (80 x 100mm) or circular (75mm dia) reflectorised panels at the top (see **Fig. 16.21**). For additional guidance, such panels may also be fixed on reverse side of posts fixed on the right hand side. These too should be white in colour.


150 mm
150 mm
150 mm
ABOUT 800-900 mm
200-300 mm
DELINEATOR POSTS
150
150
REFLECTOR (80X120mm) MADE FROM RED RETRO - REFLECTIVE SHEETING (HI GRADE) TO IRC 801 SPECIFICATION ON METAL PLATE RECESSED INTO CONCRETE. SECOND WITH WHITE REFLECTIVE SHEETING ON BACK. (ORIENT IT FOR FACING TRAFFIC ON LEFT)
BLACK
WHITE
900
1600
1600
GL
GL
M20 CONCRETE
700
150
100
CHAMFER 20 x 20
8mmø 4 NOS
6mmø STIRRUP 250mm c/c
SECTION

Delineator Posts **Concrete Delineator**

Fig. 16.21 Typical View of Delineator

Application

- The decision to use roadway indicators, whether continuously or in short sections selectively, will be guided by factors such as importance of the road, volume of fast traffic, speed of travel, crash experience, danger posed by any specific deficiency in the road alignment, etc.
- Primary use of roadway delineators is in curved reaches.
- Unless road and traffic conditions so warrant, their use in urban sections will normally not be necessary, nor on roads which are adequately lighted.

Criteria for use

i) Curved Sections
  a) Horizontal curves of radius 1000m or less
  b) Vertical curves with inadequate visibility

ii) Straight Sections
  a) Road sections where visibility is often poor due to mist, fog or snowy conditions
  b) Reaches where the alignment appears uncertain to the driver, e.g. pavement width transitions, temporary road diversions, etc.
  c) Road sections subject to frequent submergence and ponding due to storm water
  d) Approaches to narrow bridges and culverts
  e) Valley side of hill roads
  f) Road embankments exceeding 3m in height
  g) Approaches to important intersections
  h) Special problem points such as causeways and tunnels.

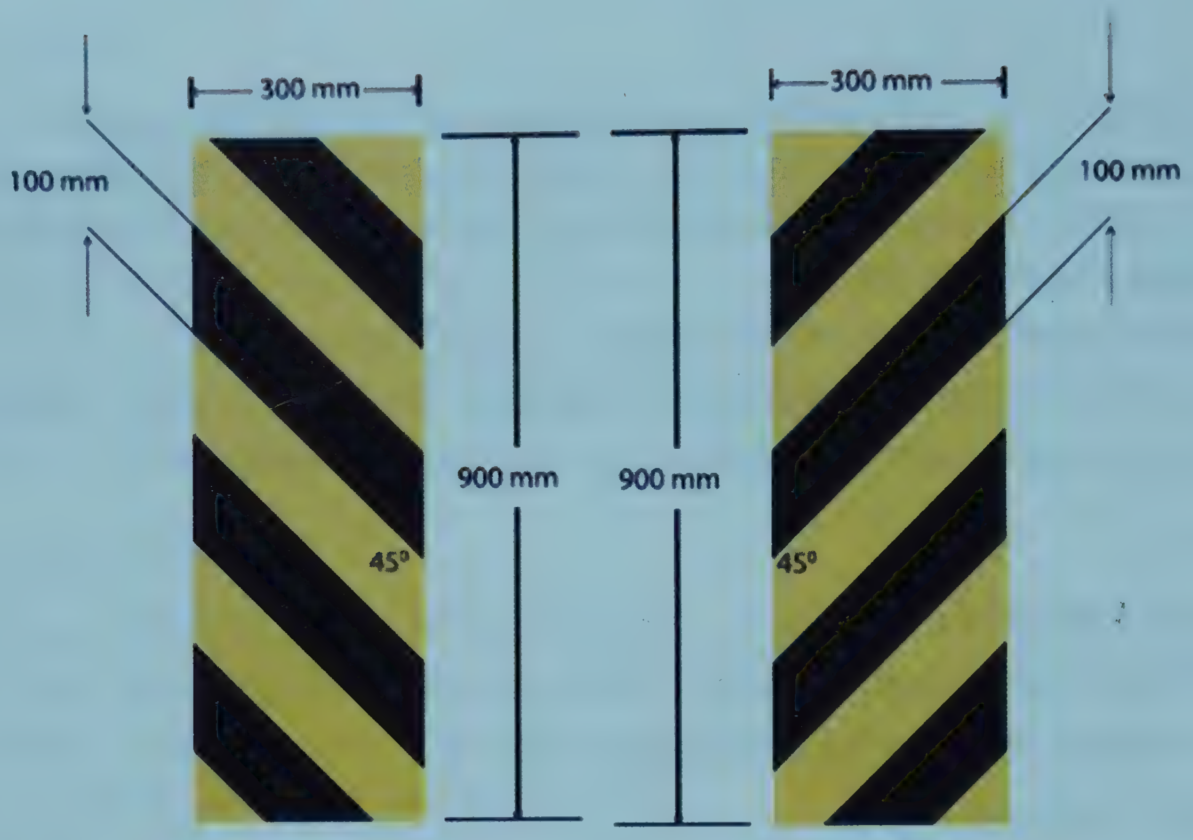
Placement and Spacing

- As a general rule, delineator posts should be erected at the edge of the usable shoulder, and in the case of kerbed sections at a distance of 0.6 to 1.5m from the kerb face.
- The overall line of posts should be parallel to centre line of the road ordinarily, except that at guard-rails or other obstructions, it may be so adjusted that the delineators are in line with or inside the innermost edge of the obstruction.

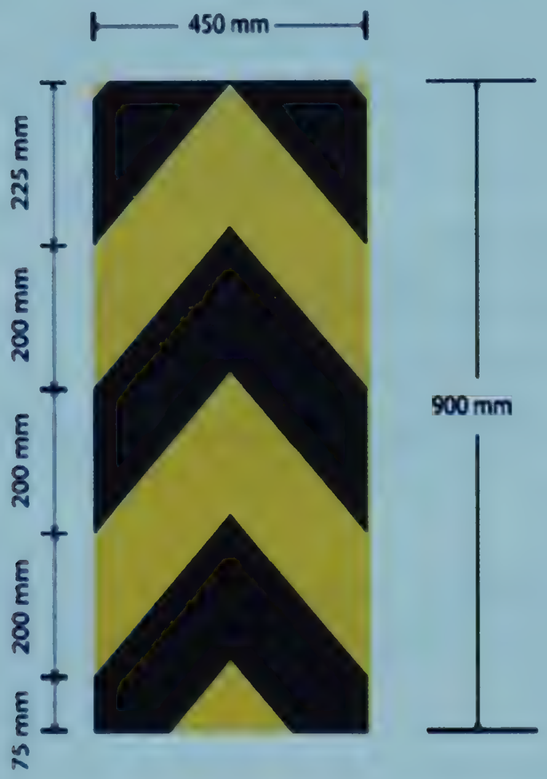
16.7.2 Hazard Markers

Design

- Any of the following two designs may be adopted for hazard makers:
  i) Type I. A marker consisting of three red reflectors arranged vertically (see **Fig. 16.22**).
  ii) Type 2. Striped markers consisting of alternately black and yellow stripes sloping downward at an angle of 45° towards the side of the obstruction on which the traffic is to pass (see **Fig. 16.22**). If possible, reflectorised paint may be used for this purpose.



Hazard Marker (Left) Hazard Marker (Right)



Two Way Hazard (Right)

Fig. 16.22 Hazard Marker

- Hazard markers should be put-up wherever there are objects so close to the road as to constitute an accident hazard, e.g. bridge abutments, guard-rails etc. Either of the two -designs, Type I or Type 2, could be used for the purpose.
- The markers should be erected immediately ahead of the line of obstruction, for instance on a narrow bridge just where the bridge rail starts. When placed in conjunction with a guardrail on a bridge approach, the hazard markers should be located immediately behind the guard-rail and at sufficient height to ensure that these will be properly visible to the oncoming traffic. The inside edge of the markers should be in line with the inner edge of the obstruction as far as possible.

16.7.3 *Object Markers*

Design

- Several designs of object markers are possible. These consist basically of circular red reflectors arranged on triangular/rectangular panels, or alternately all-red reflectors mounted similarly. The markers may be bigger if the conditions so warrant.
- At problem locations, red reflectors may also be used independently, for instance inset on the face of the kerb.

Application

- Typical locations where object markers should be used are:
  - i) Traffic islands at approaches to intersections;
  - ii) Around periphery of rotary islands;
  - iii) Median openings;
  - iv) Facing approaching traffic at islands forming left infiltration lanes;
  - v) On medians/islands on far side of the intersections;
  - vi) At points where traffic divides into different directions e.g. down ramps of a grade separated intersection, and
  - vii) On far side of T-junctions and street dead ends
- Object markers need not, however, be put up on islands provided with lighted bollards.

Placement

- The markers should be erected facing the traffic close to the point where the obstruction within the roadway starts, for instance in the case of a channelizing island at its nose point.
- No part of the object marker should, however, encroach upon the carriageway.
- To ensure this, it is desirable that the markers should be set back from the face of the kerb a distance of at least 0.5 metre.
- Height of object markers might vary depending upon the situation, but should be generally around 0.4 to 0.5m so that reflectors are fully visible to the approaching traffic.

16.7.4 *Installation of Delineators*

- Techniques of installation can vary according to nature and stiffness of the ground.
- In hard ground, posts may be installed by burying or pressing them into the ground.
- If the ground is not stiff enough, a proper foundation, whether prefabricated or cast-in-situ, will be desirable. Installation should ensure that the post does not change its orientation, particularly when it is of a circular shape.
- The delineators should be so positioned that the reflectorised or painted face is perpendicular to the direction of travel.

16.7.5 *Maintenance of Delineators*

- Iron, wooden or concrete posts should be repainted regularly.
- To remove dirt, the reflective unit should be scrubbed clean periodically, especially after rains.
- The ground around the delineators should be kept clean by cutting grass and bushes periodically so that visibility of the delineators is not affected.

16.8 Safety in Construction Zones

16.8.1 *Context*

The road work zones are areas of conflict between normal operating traffic, construction workers, road building machineries and construction traffic. If it is new road, normal operating traffic will not be there but care has to be taken to avoid and/or remove conflicts between workers and construction machineries and construction traffic. Problem becomes more serious, if it is an urban road with significant proportion of vulnerable road users.

To ensure safety of all, there is a need to adopt an efficient and effective plan for management of traffic in work zones. Work Zones Traffic Management Plans (WTMPs) are required to meet the safety needs of regular traffic as well as works traffic, ensuring minimum disruption in access to properties and movement of pedestrians. For details refer IRC:SP:55 Guidelines for Traffic Management in Work Zones.

16.8.2 *Basic Principles of Work Zone Traffic Management Plans*

The basic principles governing the design of roadways should also govern the design of Work Zones Traffic Management Plans (WTMPs). While designing the WTMP, all care needs to be taken so that anyone coming along the road or the footpath from any direction understands exactly what is happening and what is expected of him/her.

The aim should be to facilitate the passage of road users through such work zones using roadway geometrics, roadside features, and Traffic Control (TC) devices comparable to those for normal highway operations. Thus, road user movement should be free from any hazard with the following aspects in view:

- WTMP at work sites should be designed on the assumption that drivers will only reduce their speeds if they clearly perceive a need to do so. Frequent and abrupt changes in geometrics such as lane narrowing, dropped lanes or main roadway transitions, that require rapid manoeuvres, need to be avoided.
- Bicyclists and pedestrians, including those with disabilities, should be provided with access and safe passage through the work zones. Bicyclists and pedestrians should be guided in a clear and positive manner while approaching and traversing the work zones.
- Roadway occupancy should be scheduled during off peak hours, and if necessary, night work should be considered after carefully assessing its pros and cons.
- Road users and worker safety and accessibility in work zones should be an integral and high-priority element of project, from planning through design and construction.

- Early coordination with officials having jurisdiction over the affected cross streets, and those providing emergency services, should take place before roadway or side street closings.
- Special plan preparation and coordination with transit, other highway agencies, law enforcement and other emergency units, utilities, schools, and railways are needed.
- If the work zone includes a highway-rail at-grade level crossing, early coordination with the railways should take place.
- Special attention may be needed to regulate and control heavy commercial vehicle traffic in the work zones.

16.8.3 *Planning Consideration of Work Zone Traffic Management Plans*

- Provide safety for road users and workers
- Minimize hindrance or delay to road users
- Provide clear and positive guidance to road users

16.8.4 *Risks of Accidents at Construction Zones*

The following are some of common risks of accidents in construction zones

- Speeding traffic in road construction work zones.
- Inadequate sign posting and lighting and drivers failing to notice road workers.
- Drivers do not pay attention to work zone signs or flagman indicating they should slow down or come to a stop
- Drivers are driving right up to the last second and then try to force themselves in - if the other driver doesn't let them get in, they may enter the work zones and endanger the lives of workers.

16.8.5 *Aspects to Manage the Construction Zone*

Road works operations need to be carefully planned and administered to avoid accidents. Traffic management of construction zones is necessary. However, following important aspects of road safety can reduce the risk of road crashes:

- Signs must be kept clean and well maintained so as to be effective.
- Workers who control traffic must be properly trained.
- Traffic controllers must know where to stand, how to slow or stop traffic, and how to coordinate public and construction traffic movements.
- Traffic controllers and general road workers should wear suitable conspicuous clothing to ensure that they can be seen by motorists.
- Traffic control signs or road markings that are no longer required must be removed as they tend to confuse motorists.
- Speed limits should be consistent with safe site operations and traffic movements.
- Watch for construction equipment and workers. Construction equipment entering and exiting a work zone without warning, equipment extending into traffic, and construction crews and flaggers working dangerously close to moving traffic are a few examples of the hazards to expect.

16.8.6 *Safety Aspects for Workers at Construction Zones*

Safety measures are also to be taken to protect the workers:

- Wearing sunscreen, a hard hat, and long-sleeved shirts to protect from sunburn, dehydration, and overheating.
- Drinking of water to help prevent dehydration.
- Use personal protective equipment (such as hard hats and steel-toed shoes).
- Reflective clothing.
- Workers should be constantly reminded to remain vigilant and alert.

16.8.7 *Management of Traffic in Construction Zone*

The primary objective of traffic management is to manage the traffic as efficiently and safely as possible under all work conditions. The second objective is to lay down procedures to be adopted by contractor site staff to ensure the safe and efficient movement of traffic and also to ensure the safety of workers at site undertaking the construction.

Traffic control aims to give adequate warning and clear information to motorists about the nature of works on site. This will translate into correct actions required in order to pass the work site safely. Traffic control shall also include measures to safeguard pedestrians when necessary. Proper traffic control also protects those who are directly involved in carrying out the works.

16.8.8 *Elements of Temporary Traffic Control Zone (***Fig. 16.23***)*

- **Advance warning zone:** It is the zone to warn the road users of approaching hazard and prepare them for the change in driving conditions.
- **Approach transition zone:** Transition zone is that section where road users are redirected from their normal path by strategic use of tapers or with circular curves.
- **Activity Zone:** The activity zone is the section where the construction activity takes place. It comprises the work space, the traffic space, and the buffer space.
- **Terminal transition zone:** In the terminal transition zone, the traffic will be redirected from the deviated path to their normal path through the transition zone, which also can be achieved through tapering or through circular curves.
- **Work zone end zone:** The work zone end length shall extend from the end of terminal taper length to the last traffic control device such as sign showing the end of the road work, if posted. An end road work sign, speed limit sign, or other signs may be used to inform road users that they can resume normal operations.

16.8.9 *Temporary Structures Safety*

Formwork, scaffolds, and work at height, working platform, ladders, ramps etc. are referred to as temporary structures and they are required for the construction of permanent structures. According to IS 6461 Part V, formwork (shuttering) is a complete system of temporary structure built to contain fresh concrete so as to form it to the required shape and dimensions and to support it until it hardens sufficiently to become self-supporting. It includes the surface in contact with the concrete and all necessary supporting structure.

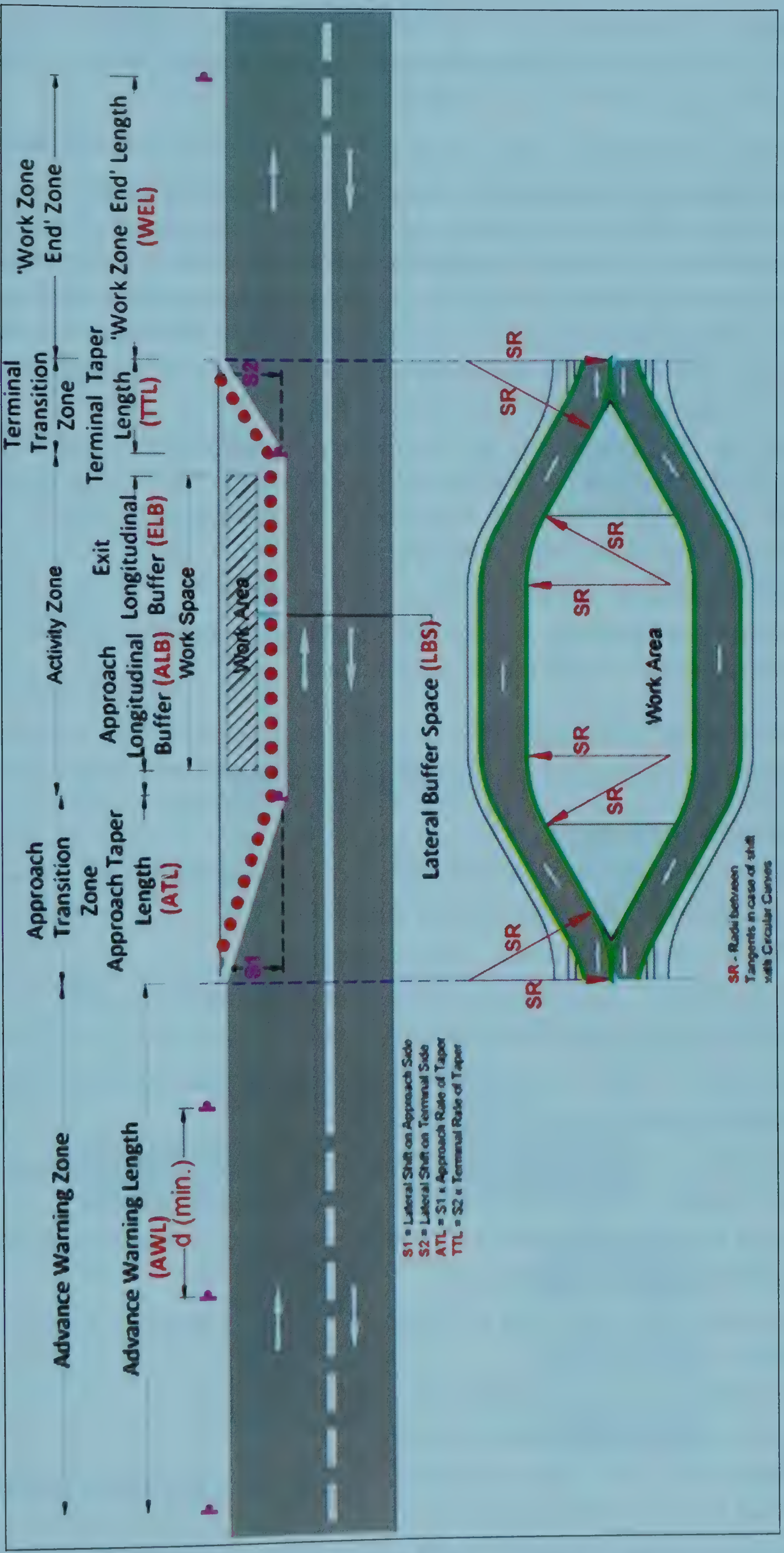

Advance Warning Zone
Advance Warning Length (AWL)
d (min.)
Approach Transition Zone
Approach Taper Length (ATL)
S1
Activity Zone
Approach Longitudinal Buffer (ALB)
Work Space
Exit Longitudinal Buffer (ELB)
Work Area
Terminal Transition Zone
Terminal Taper Length (TTL)
S2
'Work Zone End' Zone
'Work Zone End' Length (WEL)
Lateral Buffer Space (LBS)
SR
SR
SR
SR
SR
SR
SR
SR
Work Area
S1 = Lateral Shift on Approach Side
S2 = Lateral Shift on Terminal Side
ATL = S1 x Approach Rate of Taper
TTL = S2 x Terminal Rate of Taper
SR - Radii between Tangents in case of shift with Circular Curves

Fig. 16.23 Temporary Traffic Control Zone

The terms sheeting (sheathing), form (shutter), false work, centring, mould, and scaffold (scaffolding) are commonly used in the context of formwork which must be clearly understood. The definition given in IS 6461 Part V is reproduced.

- **Sheeting (Sheathing):** That part of the form, which is in contact with the concrete.
- **Form (Shutter):** (a) that part of formwork, which consists of the sheeting and its immediate supporting or stiffening members. (b) A temporary structure or mould for the support of concrete while it is setting and gaining sufficient strength to be self-supporting.
- **False work:** (a) False work is the temporary structure erected to support work in the process of construction. It is composed of shores, formwork for beams or slabs (or both) and lateral bracing. (b) That part of formwork, which supports the forms usually for a long structure, such as a bridge or flyover.
- **Centering (Centering):** It is a temporary supporting structure to a soffit. It is the specialized formwork used in the construction of arches, shells, and space structures where the entire false work is struck or decentred as a unit to avoid introducing injurious stress in any part of structure.
- **Mould:** A frame for casting, precast concrete units.
- **Scaffold (Scaffolding):** A temporary structure for gaining access to higher levels of the permanent structure during construction.

16.8.10 *Preparation of Formwork Plans*

The formwork plans should include the following information:

1. Design assumptions
2. Types of materials, sizes, lengths, and connection details
3. Sequence of removal of forms and shores
4. Details of anchors, form ties, shores, and braces
5. Field adjustment of the form required during placing of concrete
6. Details of working scaffolds and gangways
7. Weepholes, vibrator holes, or access doors for inspection and placing of concrete
8. Construction joints and expansion joints
9. Sequence of concrete placements and minimum/maximum elapsed time between adjacent placements
10. Chamfer strips or grade strips for exposed corners and construction joints
11. Foundation details for falsework
12. Special provisions such as protection from flood water, ice, and debris at stream crossings
13. Form coatings and release agents
14. Means of obtaining specified concrete
15. Location of box outs, pipes, ducts, conduits and miscellaneous inserts in the concrete, attached to or penetrating the forms
16. Location of spacing of rubber pads where shutter vibrations are used.

CHAPTER 17

TRAFFIC CALMING MEASURES

17.1 Introduction

Roads of different categories and in different terrains are designed for designated design speeds at which vehicles can travel. However, at certain locations in urban settlements depending upon the land-use, such as sharp curves, residential streets, etc., control of speed becomes necessary to promote orderly traffic movement and improved safety. Road engineering approaches aimed at bringing the design of road in accordance with the desired speeds of the vehicles plying on them constitute the guiding principles of "traffic calming or in other words speed management by design" and is becoming increasingly acceptable strategy by transportation professionals and urban local bodies. Traffic calming is an approach to "reduce speeds", which is turn ensures reduction in frequency of accidents crashes or lower degree of severity even in case of crashes. The approach is helpful especially for vulnerable road users such as pedestrians, cyclists and motorized 2-wheeler users having significant presence on urban roads and streets. This chapter draws heavily from the IRC publication IRC:99 "Guidelines for Traffic Calming Measures in Urban and Rural Areas".

17.2 Guiding Principles

Two main principles for speed reducing measures are: visual measures such as signs for speed limit, painted strips across the road, zebra crossing, STOP marking on pavement and physical measures such as humps, rumble strips, road narrowing, chicanes. It is common experience that visual measures alone may not suffice to control driving speeds but they have significant effect when combined with physical measures. The advantage of applying traffic calming measures is that these are self-enforcing and normally do not require any complicated traffic control devices.

17.3 Classification of Traffic Calming Techniques

The classification of traffic calming techniques is reproduced here from IRC:99. See **Fig. 17.1**.

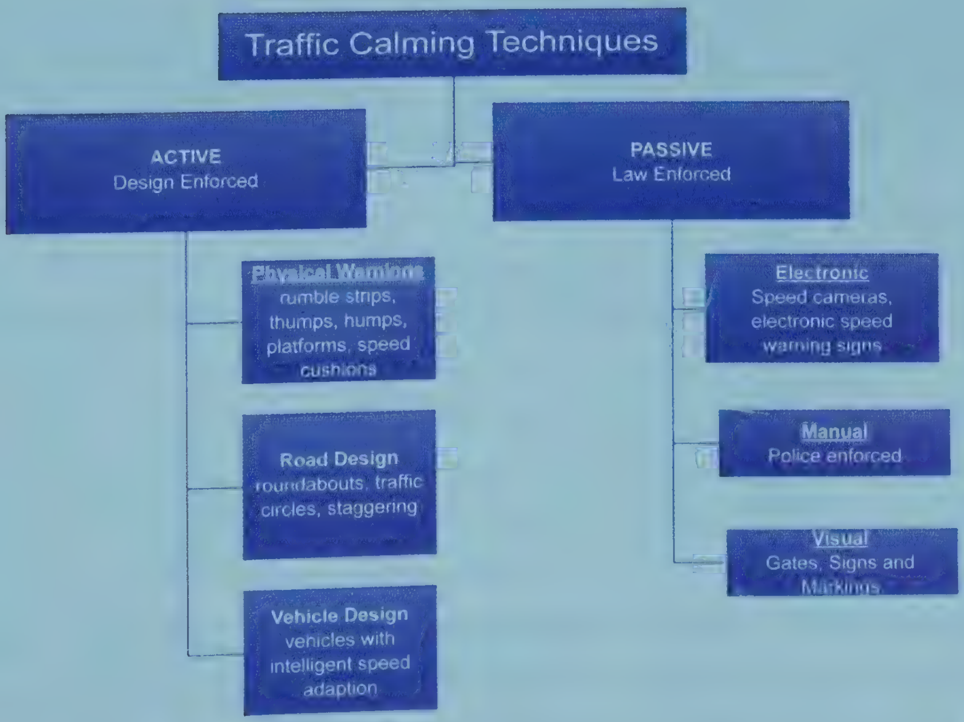

Traffic Calming Techniques
ACTIVE
Design Enforced
PASSIVE
Law Enforced
Physical Warnings
rumble strips, thumps, humps, platforms, speed cushions
Road Design
roundabouts, traffic circles, staggering
Vehicle Design
vehicles with intelligent speed adaption
Electronic
Speed cameras, electronic speed warning signs
Manual
Police enforced
Visual
Gates, Signs and Markings

Fig. 17.1 Classification of Traffic Calming Techniques

17.4 Traffic Calming Measures in Urban Areas

The principal techniques used to calm traffic fall into four areas:

- Vertical deflections
- Horizontal deflections
- Road narrowing
- Central islands

The effects of these measures may be reinforced by a range of supporting measures.

17.4.1 *Vertical Deflections*

Vertical shifts in the carriageway are effective and reliable speed reduction measures. Some of the techniques available to achieve include:

- Speed breakers
- Rumble strips
- Speed bumps
- Speed tables
- Uneven road surface and stone set pavement

- **Speed Breakers/Road Humps**

Speed breakers may be of several varieties, the rounded and flat topped being the most common. The latter are particularly suitable in providing crossing places for pedestrians. The width of humps may be restricted to allow for the longitudinal drainage.

Circular Hump: The profile of circular shaped hump is based on the shape of a circular arc with a radius varying from 11m to 113m and a chord length varying from 3.0m to 9.5m to achieve desired speed of 20km/h to 50 km/h (**Table 17.1**). Circular shaped humps with rises less than assumed 10 cm will result in higher speeds than those mentioned. Rises that are higher than 10cm may cause damage to vehicles. **Fig. 17.2** gives the geometrical details of Road Hump.

Table 17.1 Recommended Radii and Chord Lengths for Circular Humps (assumed rise = 10 cm)

Desired speed (km/h)	Radius (m)	Chord length (m)	Bus speed during passage (km/h)
20	11	3.0	5
25	15	3.5	10
30	20	4.0	15
35	31	5.0	20
40	53	6.5	25
45	80	8.0	30
50	113	9.5	35

Trapezoidal Humps: A hump, which constitutes a 50 to 100 mm, raised flat section of a carriageway with ramps on both sides is called a trapezoidal hump. **Fig. 17.3** gives geometric details of trapezoidal hump for various speeds and also the speeds at which the buses may reasonably pass the individual humps.

Table 17.2 Recommended Ramp Lengths and Gradients for Trapezoidal Humps

Desired speed (km/h)	Length of ramp (m)	Gradient	Bus speed during passage (km/h)
20	0.7	1:7	-
25	0.8	1:8	5
30	1.0	1:10	10
35	1.3	1:14	15
40	1.7	1:16	20
45	2.0	1:20	25
50	2.5	1:25	30

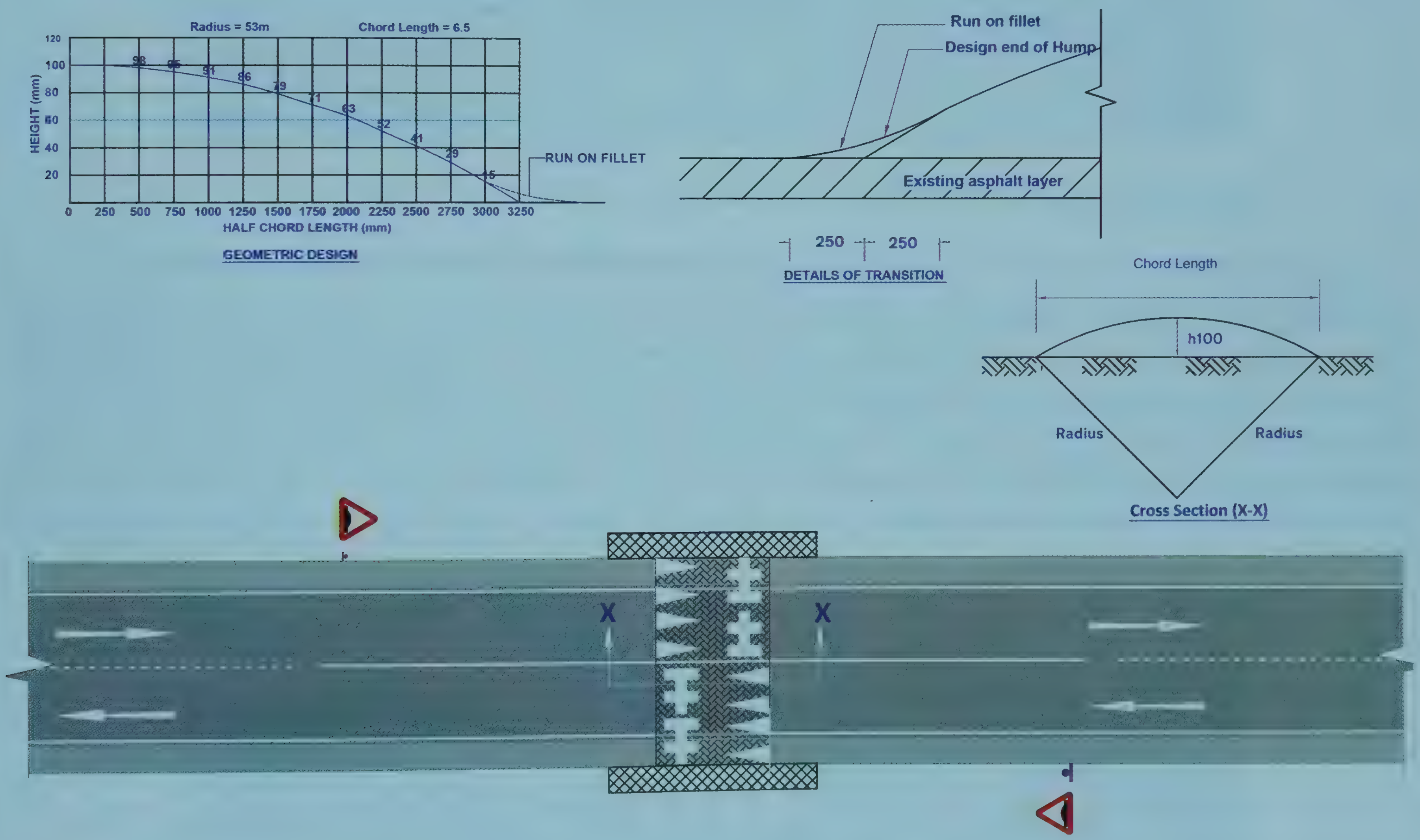

Radius = 53m
Chord Length = 6.5
HEIGHT (mm)
120
100
80
60
40
20
98
95
91
86
79
71
63
52
41
29
15
RUN ON FILLET
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
HALF CHORD LENGTH (mm)
GEOMETRIC DESIGN
Run on fillet
Design end of Hump
Existing asphalt layer
250
250
DETAILS OF TRANSITION
Chord Length
h100
Radius
Radius
Cross Section (X-X)
X
X

Fig. 17.2 Geometric Details of Circular Road Hump

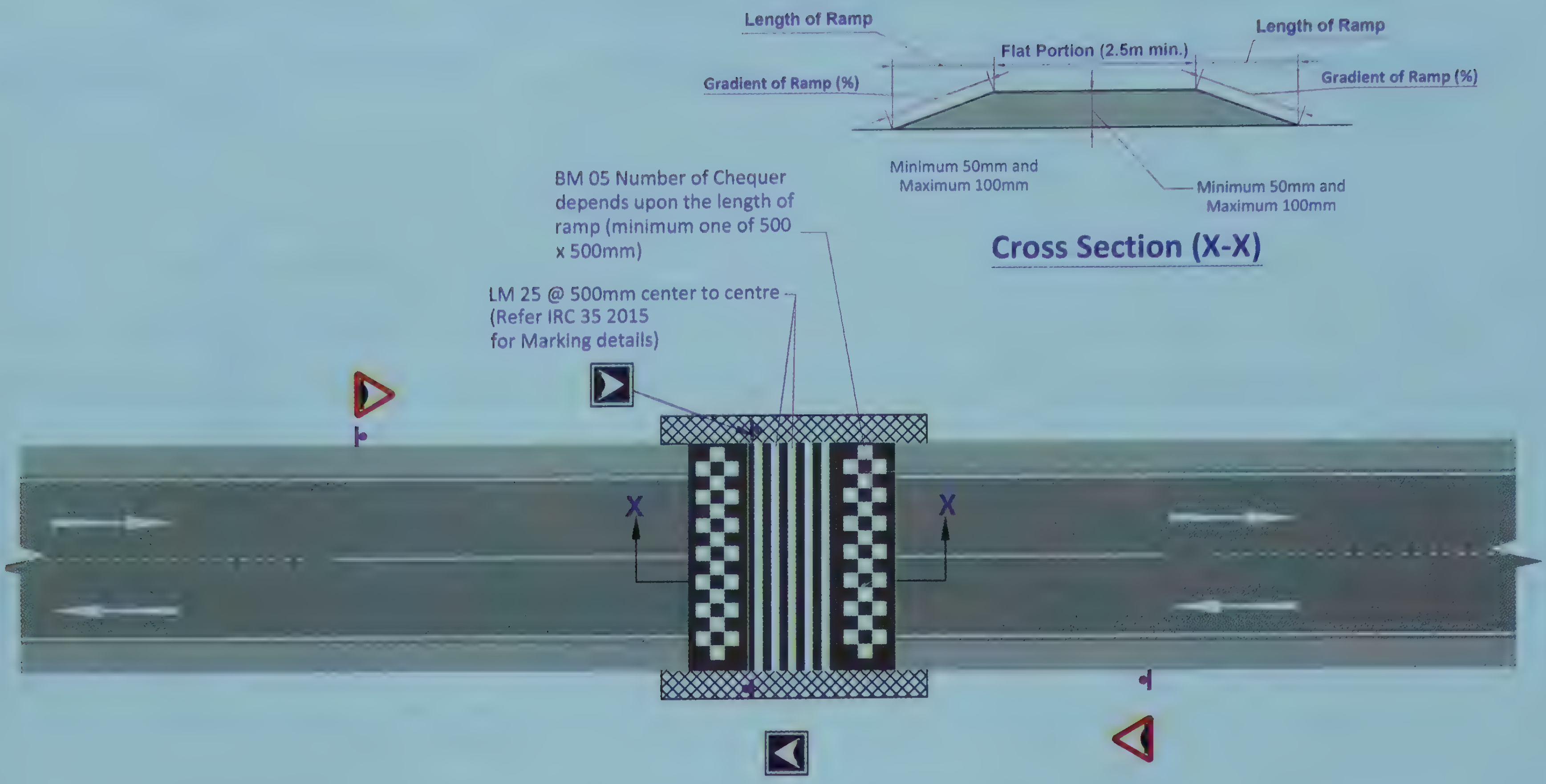

Length of Ramp
Flat Portion (2.5m min.)
Length of Ramp
Gradient of Ramp (%)
Gradient of Ramp (%)
Minimum 50mm and Maximum 100mm
Minimum 50mm and Maximum 100mm
Cross Section (X-X)
BM 05 Number of Chequer depends upon the length of ramp (minimum one of 500 x 500mm)
LM 25 @ 500mm center to centre (Refer IRC 35 2015 for Marking details)
X
X

Fig. 17.3 Geometric Details of Trapezoidal Road Hump

- **Rumble Strips**

Rumble strips are provided at places where speed control is unavoidable say on highways and arterial roads. Properly designed rumble strips can be provided on NHs and State Highways. The rumble strips can be cast in situ with cement concrete or premix bituminous materials. Rumble strips may be provided across the entire width of carriageway or paved shoulders. Raised section should be 20 to 30mm high, 200-300mm wide and spaced about one meter centre to centre and roughly 6 numbers at one location as shown in **Fig. 17.4**. These are placed across the entire carriageway including the shoulder. Proper workmanship must be exercised to achieve the required height.

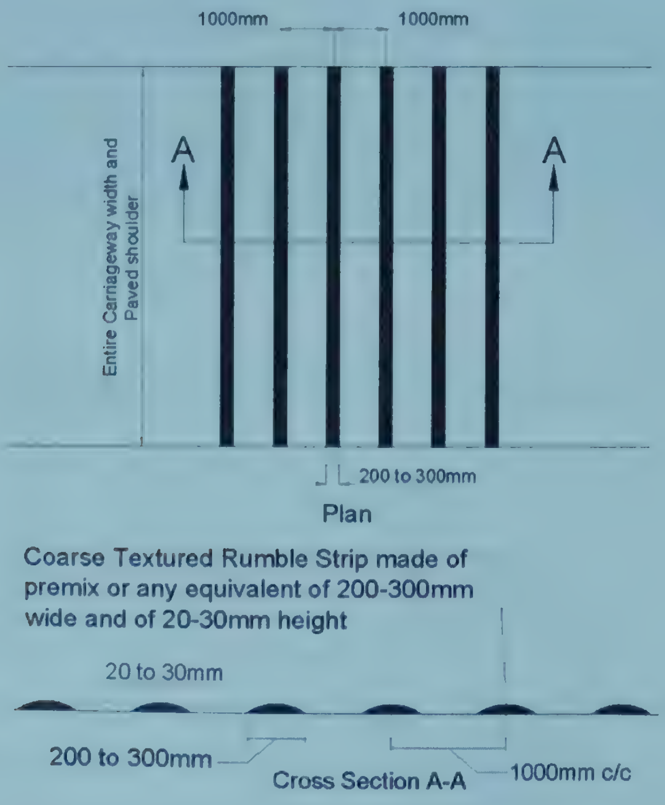

1000mm
1000mm
A
A
Entire Carriageway width and Paved shoulder
200 to 300mm
Plan
Coarse Textured Rumble Strip made of premix or any equivalent of 200-300mm wide and of 20-30mm height
20 to 30mm
200 to 300mm
Cross Section A-A
1000mm c/c

Fig. 17.4 Rumble Strip (not to scale)

- **Speed Bumps**

Precast, ready to install bumps are available and are being fixed on local and collector streets. See **Fig. 17.5**.

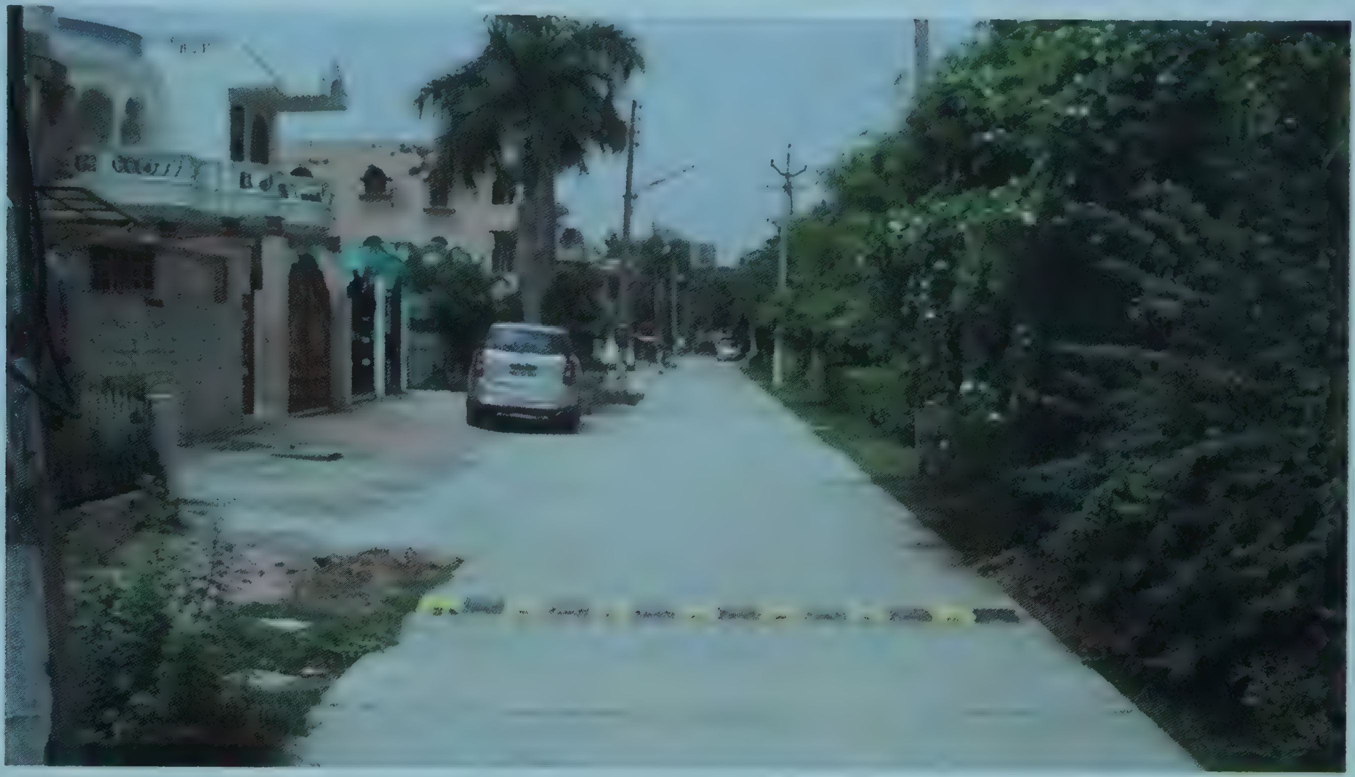


Fig. 17.5 Road Bump in Narrow Residential Street

- **Speed Table (Raised Crossings)**

Speed Table, which is the raised crossing, extends the full width of the carriageway between the kerbs and extends over a longer length of road than humps (See **Fig. 17.6**). The surface should be of a different material from that of carriageway and footpath. Speed Table is more suitable than road humps when the measures are implemented on bus routes. In a corridor having considerable buses, the length of the Speed Table should be sufficient to accommodate the full wheelbase of the bus to reduce passenger discomfort.

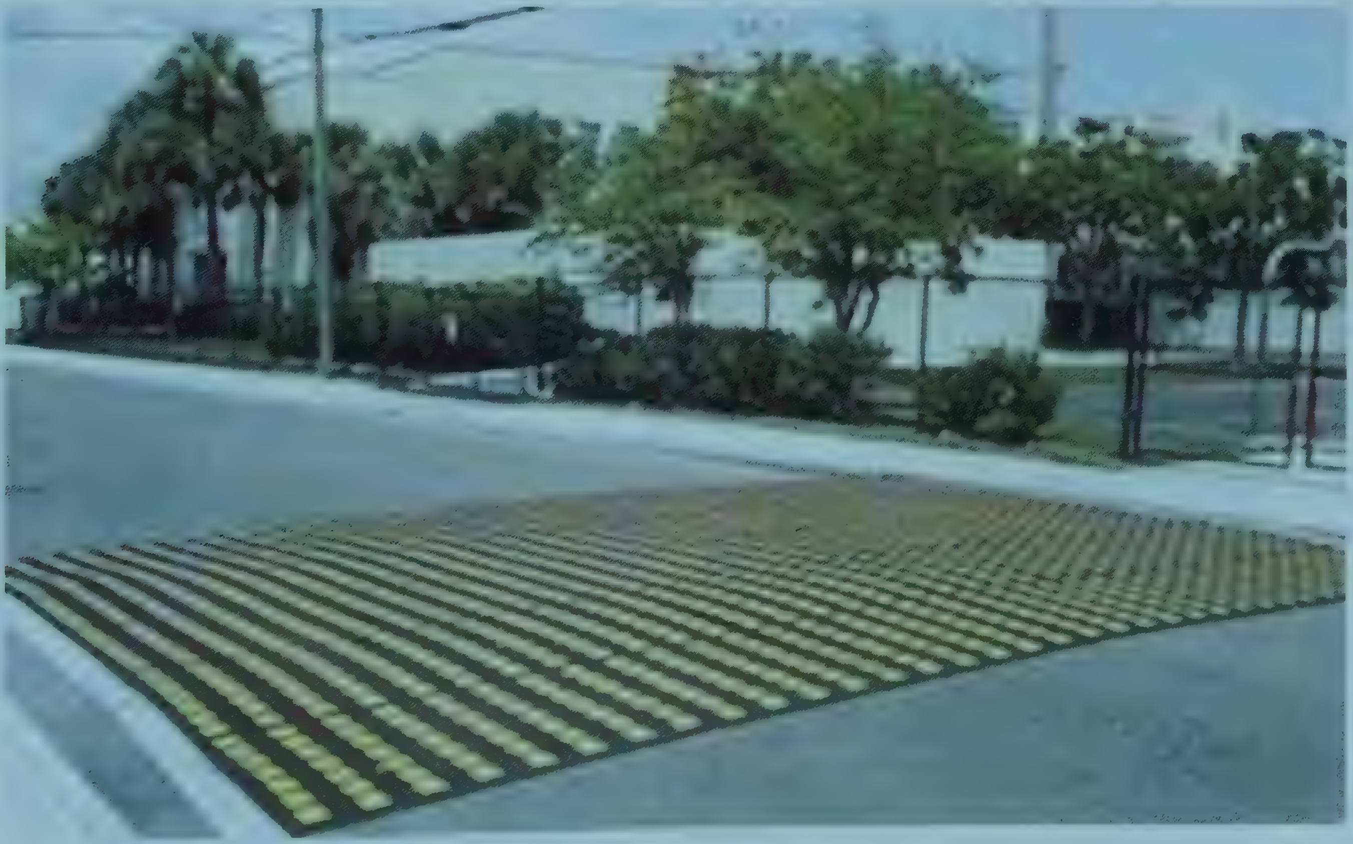


Fig. 17.6 Speed Table

- **Uneven road surface and stone set pavement**

Uneven road surface or stone set pavement as shown in **Fig. 17.7** is another way of reducing speed. By changing the surface texture, speed gets reduced due to slight discomfort.

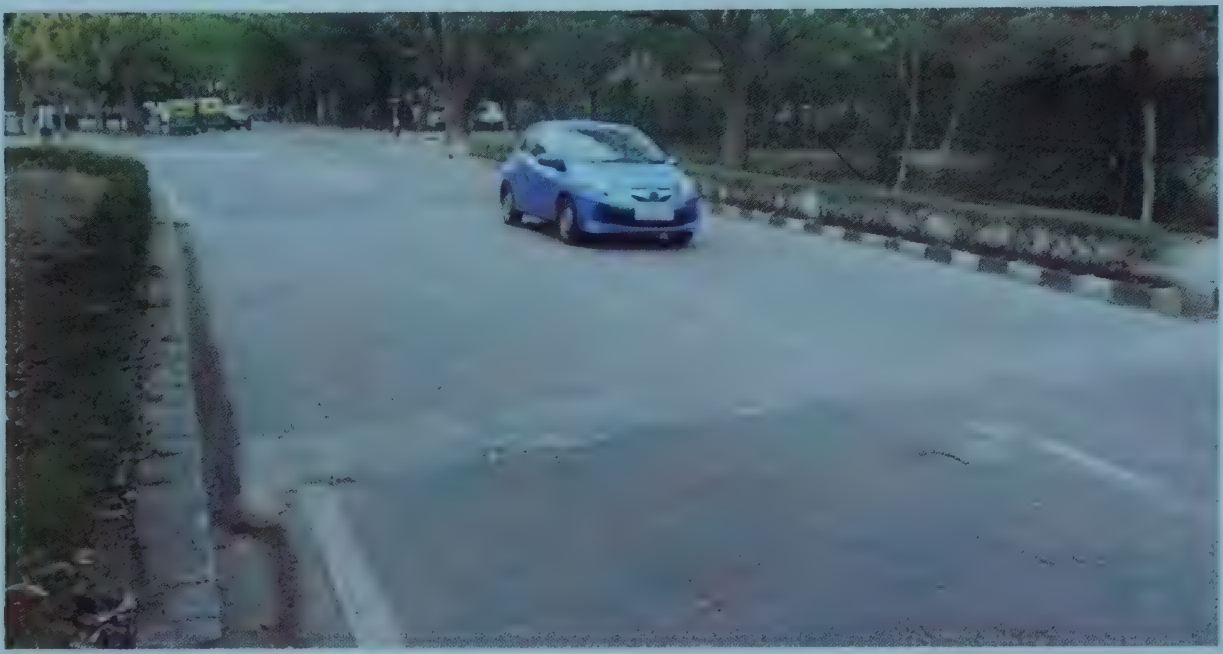


Fig. 17.7 Uneven Road Surface in IIT Delhi

17.4.2 *Horizontal Deflections*

Horizontal shifts in the carriageway are less effective than vertical ones in achieving reductions in speed. However, their impact is significantly increased when used in combination with a vertical shift. Horizontal shifts are generally gained through chicanes. The speed reducing impact of chicanes is reduced if the measure has to allow for the passage of Heavy Goods Vehicles (HGVs), wherein the wider carriageway catered for HGV does not deter car drivers to take a "racing line". The use of stone sets or similar treatment can be useful in allowing the passage of large vehicles while discouraging cars. Chicanes significantly reduce parking spaces and should therefore be avoided if spaces are at a premium. Additionally, they should not be dependent upon parked cars for their effect. Horizontal deflection by chicane shall always be provided with hazardous markings and retro-reflective hazard markers to make the chicane conspicuous at all time as shown in **Fig. 17.8**.

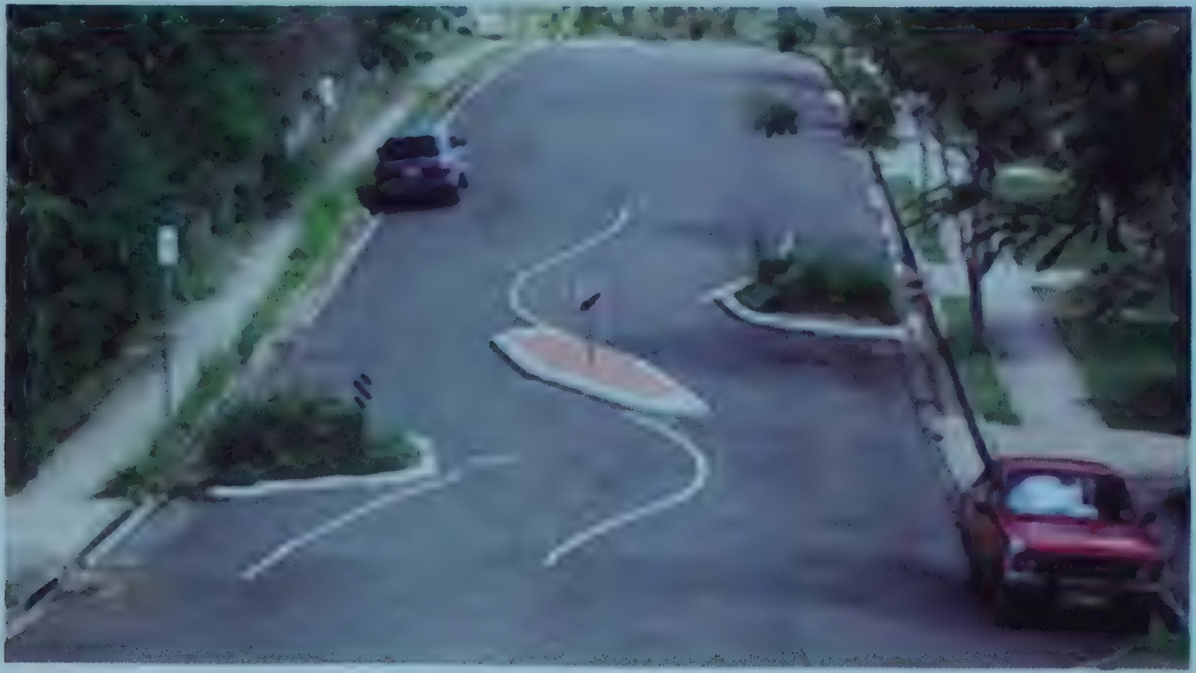


Fig. 17.8 Chicane Island to deflect the Traffic

17.4.3 *Road Narrowing*

Road narrowing can be considered as another supportive measure to vertical deflections. Extra space created by road narrowing is generally utilized to provide widened footpath.

17.4.4 *Central Islands*

Providing central islands on undivided carriageways on an urban road is another measure to achieve speed reduction as well as providing refuge to pedestrians while crossing the road.

17.5 Traffic Calming at Road Junctions

17.5.1 *Special Treatments*

Raised junction areas, and flat top road humps are effective speed reducing measures at junctions. The area of a junction may be reduced by building out the footways having considerable pedestrian crossing. This is carried out on junction corners at crossroads or T-junctions. The built out can be provided to prevent free left turn. **Fig. 17.9** shows an illustrative design for mid-block crossing and **Fig. 17.10** shows raised areas of pedestrians at junctions.

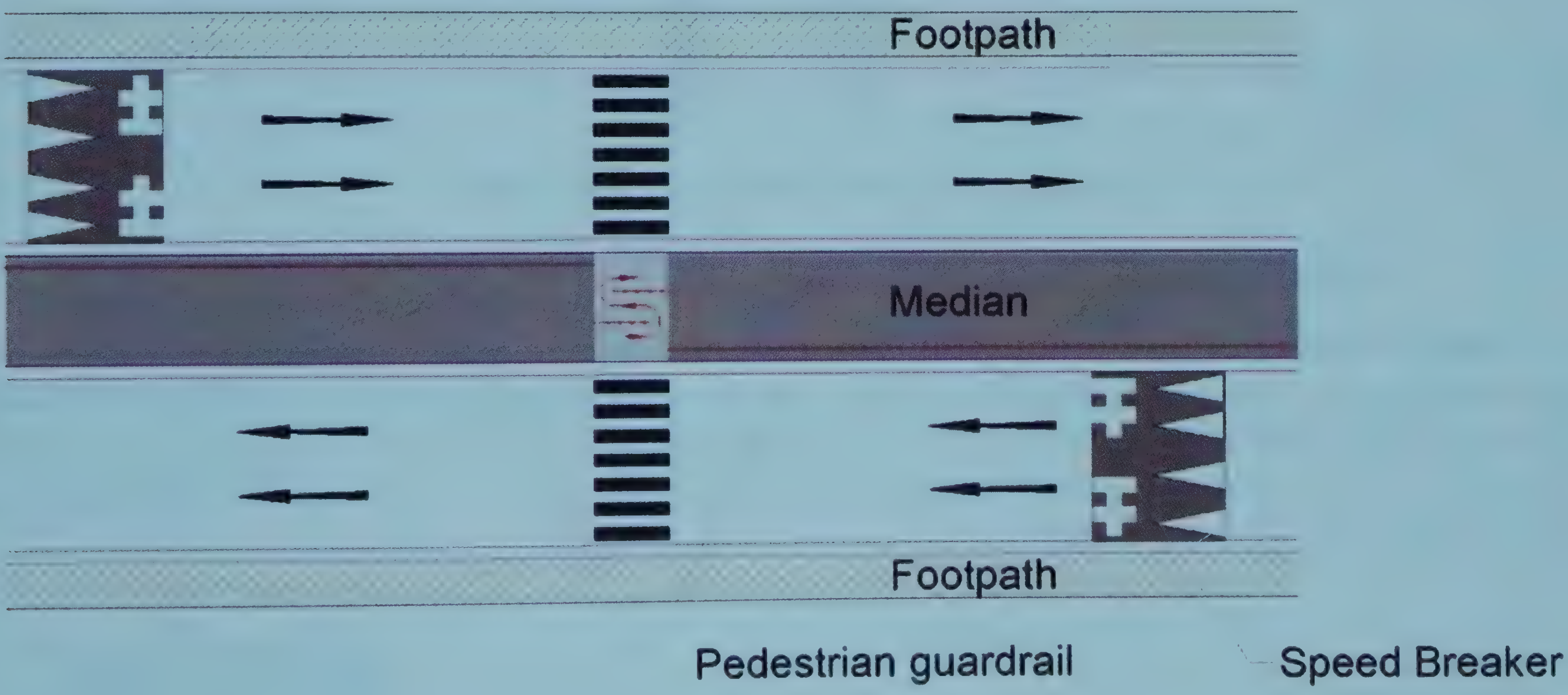


Fig. 17.9 Design to facilitate Mid-Block Crossing by Pedestrians

17.5.2 *Special Junction Forms*

Roundabouts and mini roundabouts may be useful in reducing traffic speeds at junctions. The latter is suitable when available space is limited, however, if no vertical elements are placed on the island, the speed reducing effect will be more limited. A ramped area around a central island allows more turning space for large vehicles.

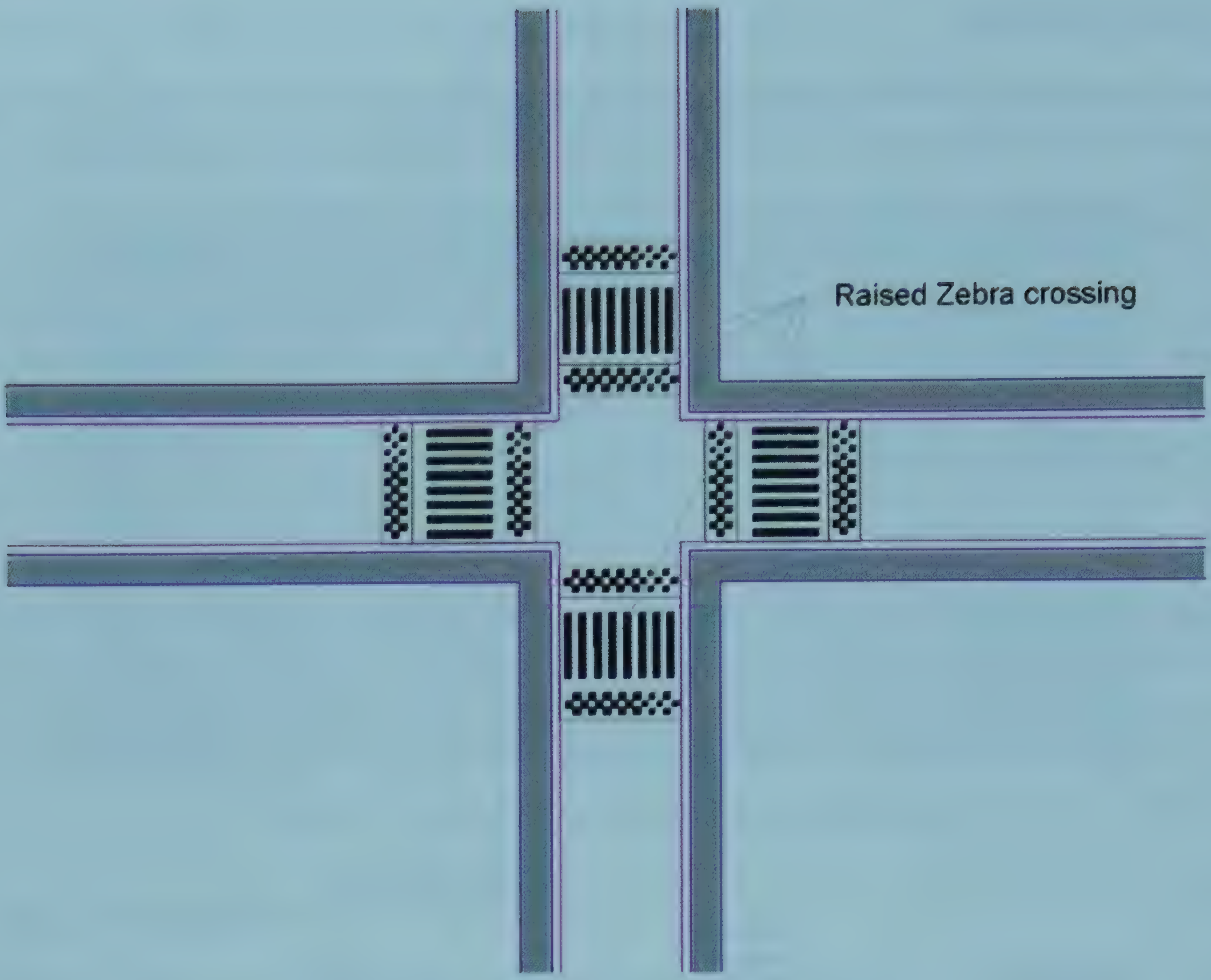
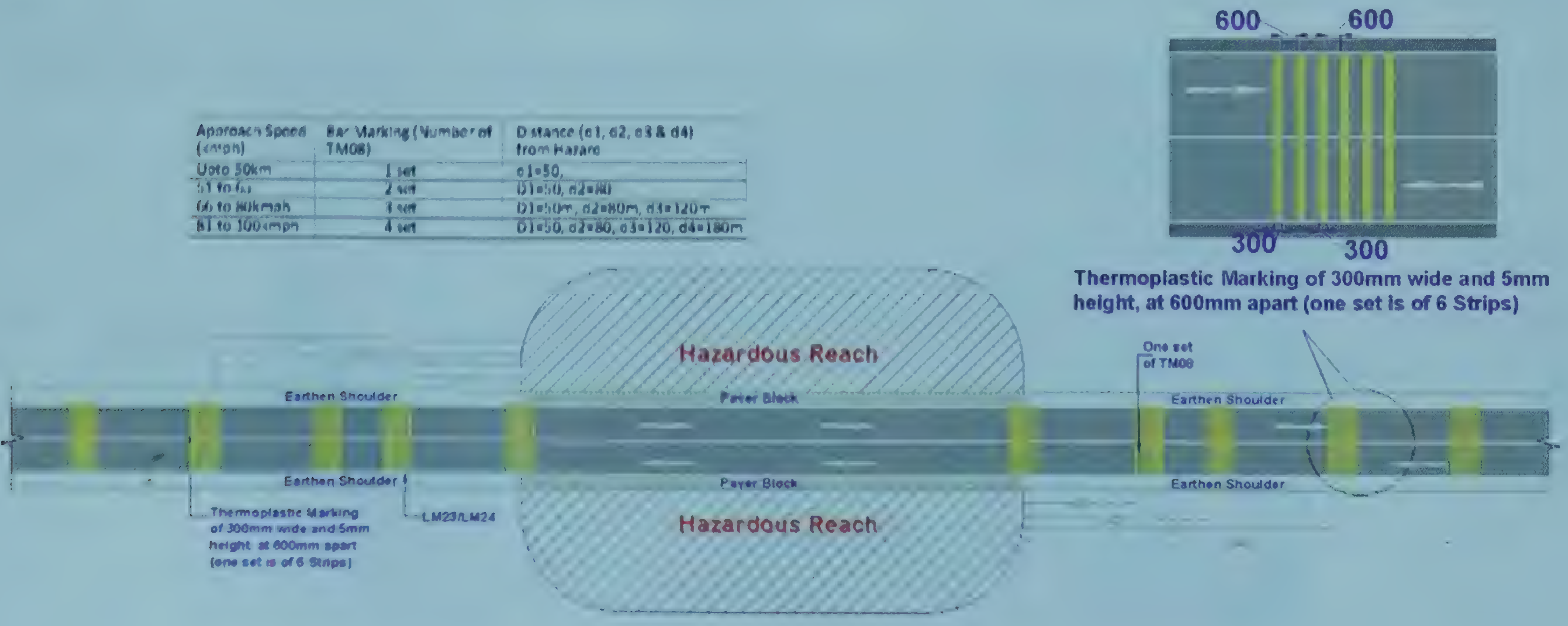

Raised Zebra crossing

Fig. 17.10 Raised Areas for Pedestrians

17.6 Traffic Calming on Arterial Roads

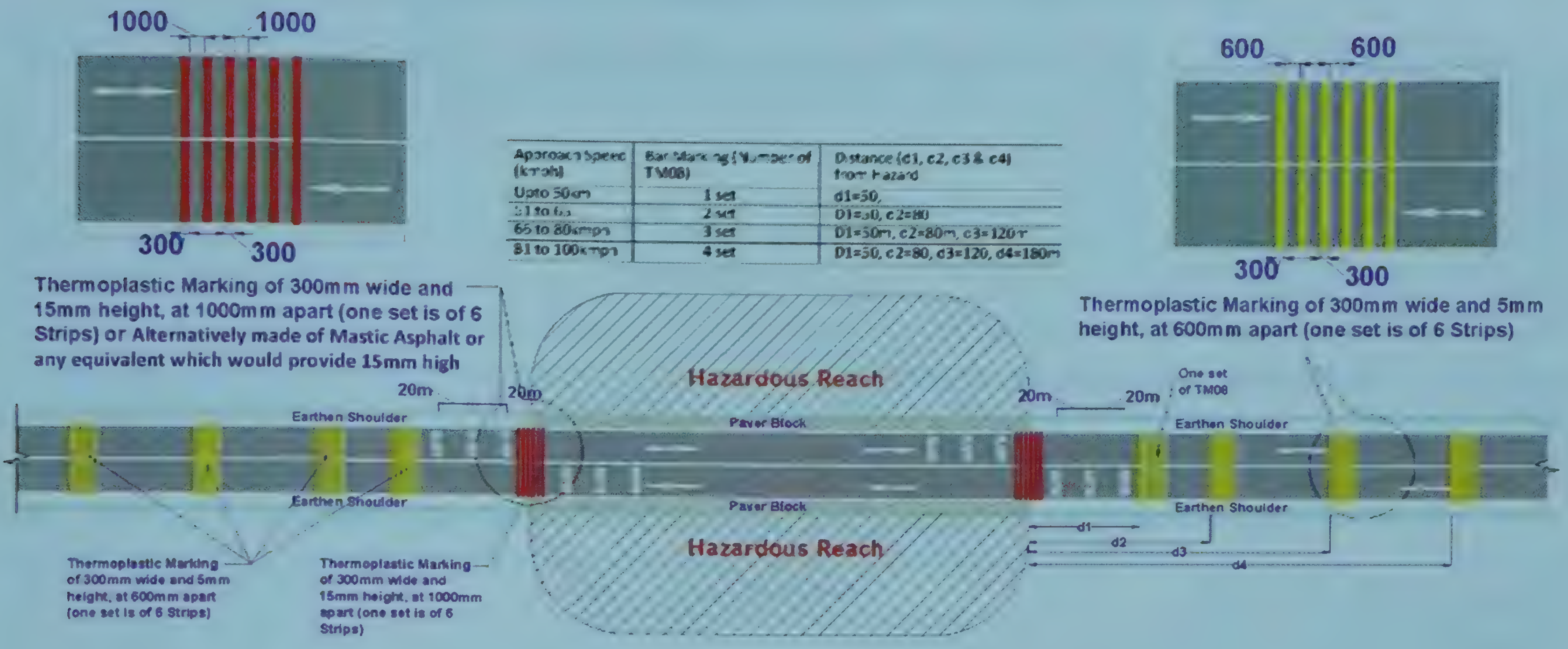
On arterial roads, changes in (surface) level are often regarded as unacceptable. Transverse bar marking is an alternative. **Fig. 17.11** gives traverse bar markings of 5mm and **Fig. 17.12** with transverse bar markings of 15mm at the boundary of speed zone. Since bar markings of 15mm expects speed reduction, a set of "SLOW" marking shall be given immediately before markings, at 20m and 40m from Bar marking.



Approach Speed (kmph)	Bar Marking (Number of TM08)	Distance (d1, d2, d3 & d4) from Hazard
Upto 50km	1 set	d1=50,
51 to 60	2 set	D1=50, d2=80
61 to 80kmph	3 set	D1=50m, d2=80m, d3=120m
81 to 100kmph	4 set	D1=50, d2=80, d3=120, d4=180m

600
600
300
300
Thermoplastic Marking of 300mm wide and 5mm height, at 600mm apart (one set is of 6 Strips)
Hazardous Reach
One set of TM08
Earthen Shoulder
Paver Block
Earthen Shoulder
Earthen Shoulder
Paver Block
Earthen Shoulder
Thermoplastic Marking of 300mm wide and 5mm height at 600mm apart (one set is of 6 Strips)
LM23/LM24
Hazardous Reach

Fig. 17.11 Transverse Bar Marking as an Alerting Measure


1000
1000
300
300
Thermoplastic Marking of 300mm wide and 15mm height, at 1000mm apart (one set is of 6 Strips) or Alternatively made of Mastic Asphalt or any equivalent which would provide 15mm high
600
600
300
300
Thermoplastic Marking of 300mm wide and 5mm height, at 600mm apart (one set is of 6 Strips)
20m
20m
Hazardous Reach
20m
20m
One set of TM08
Earthen Shoulder
Paver Block
Earthen Shoulder
Paver Block
Earthen Shoulder
Earthen Shoulder
Hazardous Reach
d1
d2
d3
d4
Thermoplastic Marking of 300mm wide and 5mm height, at 600mm apart (one set is of 6 Strips)
Thermoplastic Marking of 300mm wide and 15mm height, at 1000mm apart (one set is of 6 Strips)

Approach Speed (kmph)	Bar Marking (Number of TM08)	Distance (d1, d2, d3 & d4) from Hazard
Upto 50km	1 set	d1=50,
51 to 65	2 set	D1=50, c2=80
65 to 80kmph	3 set	D1=50m, c2=80m, c3=120m
81 to 100kmph	4 set	D1=50, c2=80, d3=120, d4=180m

Fig. 17.12 Transverse Bar Marking with Stricter Compliance

17.7 Eligibility Criteria and Area of Application

Tables 17.3 to **17.6** give the eligibility criteria and area application of different measures respectively for urban Arterial, Collector Roads, Residential Streets, and High Pedestrian Activity Zones.

Table 17.3 Traffic Calming Techniques for Arterial Roads

Arterial Road (speed limit 50 km/h)	**Pedestrian crossing**	**Left Turns**	**Intersections**
Speed hump Type 1(parabolic)			
Speed hump Type 2 (flat top)		In the middle to facilitate pedestrian crossing	
Rumble strips	10-20 m before zebra crossing		10-20 m before zebra crossing
Texture change (uncut stones)	10-20 m at zebra crossing		
Raised paint markings (audible markers)			
Paint markings	Before zebra crossing		Before zebra crossing

Table 17.4 Traffic Calming Techniques for Collector Roads

Collector Road (speed limit 30 km/h)	Pedestrian crossing	Left Turns	Intersections
Speed hump Type 1 (parabolic)			
Speed hump Type 2 (flat top)	✓		✓
Rumble strips	10-20 m before zebra crossing		
Texture change (uncut stones)			✓
Raised paint markings (audible markers)	✓		✓
Paint markings	✓		✓

Table 17.5 Traffic Calming Techniques for Residential Streets

Speed limit <20 km/h	Pedestrian crossing	Left Turns	Intersections
Speed hump Type 1(parabolic)			
Speed hump Type 2 (flat top)			✓
Rumble strips		✓	
Texture change (uncut stones)	✓	✓	✓
Raised paint markings (audible markers)	✓	✓	✓
Paint markings	✓	✓	✓

Table 17.6 Traffic Calming Techniques in High Pedestrian Activity Zones

Speed Limit 10km/h	Pedestrian crossing	Left Turns	Intersections
Speed hump Type 1 (parabolic)			
Speed hump Type 2(flat top)		To ensure safe pedestrian crossings at left turns.	All four sides for pedestrian crossings
Rumble strips	10-20 m before zebra crossing		
Texture change (uncut stones)	✓	All along the left turn lane except 4-5 m wide plane surface for wheel chairs.	✓
Raised paint markings (audible markers)	10-20 m before zebra crossing	✓	✓
Paint markings	✓	✓	✓

CHAPTER 18

DISASTER MANAGEMENT

18.1 Introduction

A disaster is a catastrophe, mishap, calamity or a grave occurrence from natural or man-made causes which is beyond the coping capacity of the affected community. It is described as a result of combination of factors: the exposure of a community to a hazard, the existing conditions of vulnerability; and insufficient capacity or measures to reduce or cope with the potential negative consequences. The impacts of disaster may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation. *(Source: National Disaster Management Authority, NDMA)*

Harm refers to personal injury or damage to property. Hazard is a situation or condition with potential to cause harm in particular circumstances. It is possible to predict the likelihood that a particular hazard will result in actual harm. The calculation of the probable circumstances in which this might occur is in essence a risk assessment. A target is that which may be harmed. The target area is the area within the zone of impact.

18.2 Disaster Risk in India

India is vulnerable, in varying degrees, to a large number of natural and man-made disasters. These include:

- Natural Disasters – Earthquakes, floods and river erosion, cyclones and tsunamis, drought, landslides and avalanches. These are based on location, exposure to weather and tectonic conditions, and vary in scale, severity and risk.
- Manmade Disasters – Fires, accidents, emergencies of chemical, biological, radiological and nuclear (CBRN) origin. A result of negligence, miscreants or a fallout of a natural or successive hazard or disaster, they too vary in scale and impact.

The vulnerability to these hazards is heightened by the expanding population, urbanisation and industrialisation, development within high-risk zones, environmental degradation and climate change. *(Source: National Policy on Disaster Management)*

18.3 Disaster Management

Disaster Management (DM) involves a continuous and integrated process of planning, organising, co-ordinating and implementing measures which are necessary or expedient for:

i. Risk assessment for disasters and hazard conditions
ii. Preparation of strategic disaster management plan based on risk assessment, value and vulnerability of target/target area and scale of severity.
iii. Preparedness to deal with any disaster through capacity building including research and knowledge management
iv. Mitigation or reduction of risk of any disaster or its severity or consequences
v. Prompt response to any threatening disaster situation or disaster

vi. Assessing the severity or magnitude of effects of any disaster

vii. Evacuation, rescue and relief

viii. Temporary shelters, facilities and staging for emergency services

ix. Rehabilitation and reconstruction

A typical DM continuum comprises six elements; the pre-disaster phase includes prevention, mitigation and preparedness, while the post-disaster phase includes response, rehabilitation, reconstruction and recovery.

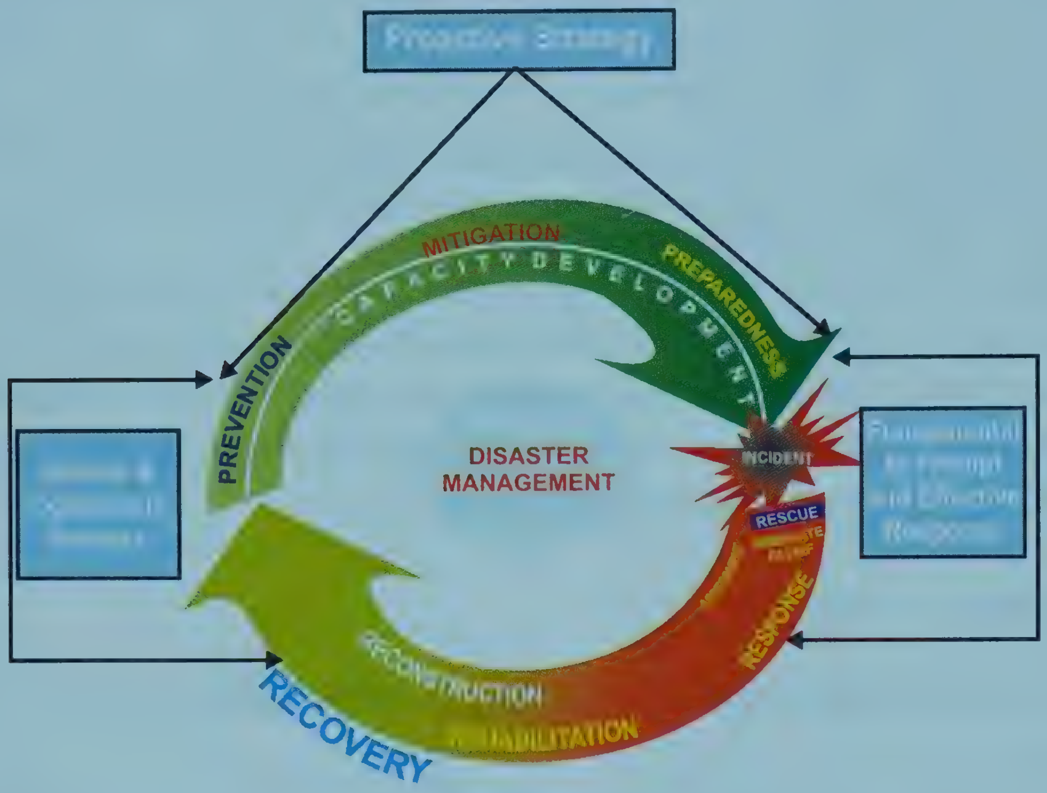

Proactive Strategy
MITIGATION
CAPACITY DEVELOPMENT
PREPAREDNESS
PREVENTION
DISASTER
MANAGEMENT
INCIDENT
Framework for Prompt and Effective Response
RESCUE
RESPONSE
RECONSTRUCTION
REHABILITATION
RECOVERY

Fig. 18.1 Disaster Management Continuum
(Source: National Policy on Disaster Management, 2009)

18.4 Disaster Resilience

It is the capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.

Effective disaster management helps in building resilience of community or society to disaster. Prevention and preparedness is a necessary part of systematic efforts to increase resilience to disaster. Better resilience will help communities bounce back better and quicker.

18.5 Roads and Disaster Management

Roads become the most critical piece of public infrastructure in the case of a disaster situation. The Road network provides access for emergency evacuation, relief supplies, repair and rehabilitation. Since there are multiple agencies acting on these issues, for coping with disasters swiftly and effectively, there is a need for the following:

- A comprehensive strategic plan for the roads and streets network
- Responsibility mapping between the different stakeholder agencies and their coordination

- Mapping of the ownership and management responsibility of different roads within the urban area.
- Road infrastructure and facilities must be designed to withstand disasters foreseeable in the urban region. Additional cost for this design and construction must be accounted for in the proposals for all new/retrofitting projects.
- Critical components of the transportation system such as junctions, signaling system signage must be designed to be fail-safe, self-correcting, and readily reparable when they get damaged.
- All disaster management strategies should value diversity, flexibility and redundancy.

18.6 Transportation and Disaster Management

Following transportation issues need attention:

- Evacuations before, during or after an event.
- Delivery of emergency supplies and services, including water, food, medical care, utility maintenance, law enforcement, etc.
- Search and rescue operations- transport of victims from collapsed structure to local hospital and shelters in case of fire/earthquake, etc.
- Creating and utilizing open areas adjacent to transport corridors for temporary relief and rehabilitation services.
- Quarantine.
- Transportation infrastructure repair.
- Conduit for emergency responses and post- disaster rehabilitation efforts.

18.7 Guidelines for Preparedness

This section highlights the measures to be adopted for disaster preparedness and mitigation. It indicates the measures that can be deployed to mitigate the vulnerabilities of transport infrastructure to natural hazards.

18.7.1 *Risk Assessment*

Identify risk factors for both man-made disasters such as collapse of structure, terrorist attacks and fires, as well as for natural disasters based on localized susceptibility of place, i.e., floods, avalanches, cyclones, earthquakes or similar hazard conditions. A ranking of risk can be based on location, target area, hazard and severity of impact, with required level of inspection and periodic risk assessment as listed below.

i. **Negligible Risk**

Remote or inaccessible areas with no public use and no high value targets

No inspection required

Occasional review of requirement

ii. **Low Risk**

Open parks, fields, roads, footpaths with occasional use and no other high value or vulnerable targets

Informal inspection required

Infrequent assessment- e.g. every 3 years is required

iii. Medium Risk

Open parks, gardens, fields, roads, footpaths with moderate use; occasionally used buildings and car parks

Routine inspection required

Regular assessment- e.g. every 2 years is required

iv. High Risk

Well used assembly points, pedestrian routes, roads, footpaths; busy buildings and car parks

Detailed inspection required

Frequent assessment- e.g. Seasonal as required

18.7.2 *Assessment of Scale of Severity*

Define a scale of severity, based on potential damage assessment, persons and property impact, location and scale of disturbance.

This includes assessment of areas where hazards/disasters have the highest risk of occurring-

- Most frequent usage
- Value and vulnerability of target
- Target Area and Population

18.7.3 *Disaster Management Plan*

Create a Centralized Strategic Plan to address emergencies, disturbances and disasters based on the scale of severity at a policy level. State and Region-specific risk factors will further determine detailed objectives and response strategies and mechanisms, enforceable at local levels.

Steps for preparing a Disaster Management Plan

i. Identify management implications of policy aims and objectives (assess and classify levels of risk impact and values of the affected place)
ii. Manage target areas around the affected place
iii. Manage site to achieve acceptable levels of risk (identify essential remedial works and routine maintenance)
iv. Define inspection cycle
v. Keep records of all works, monitoring and feedback for revaluation of emergency response
vi. Instruct specialists on the plan

18.7.4 *Guidelines*

a. Establish a clear long term strategy guiding the development of disaster resilient transport systems and define the role of various institutions (Government, private sector, CSOs and NGOs) in achieving this. It will include defining the institutional ownership and responsibility of the assets. The strategy should be prepared in consultation with all the concerned stakeholders/institutions and should be communicated to the infrastructure owners, operators, investors and insurers as well as regulators and local authorities so that it is mainstreamed in the operation, maintenance and improvement of transport assets.

b. Conduct a transport infrastructure vulnerability assessment and interdependency analysis of infrastructure systems. Inventories of critical infrastructure assets can be cross-referenced with hazard maps to identify the threat from system failure.

c. Develop an emergency action plan that identifies specifically who will do what during disasters. Update the plan regularly, particularly after a disaster event tests its effectiveness.

d. In the event of an accident occurring which results in harm, the agency with ownership may become responsible for the event. A safety policy needs to be in place. Objectives of safety policy should be –

- Use current best management practices to maintain the social, cultural and environmental value of the affected place and its people
- Maintain and enhance value of place and its people
- Awareness of hazards, risks and legal obligations
- Awareness of social, amenity or environmental factors that are valued and which may have a bearing on safety
- Awareness of the needs of vulnerable groups including persons with disabilities, children and senior citizens.
- The decision process and how it is implemented
- Recording, monitoring and feedback
- Guidance on how to proceed

e. Requirements

Various functionaries in the urban local bodies and road agencies responsible for urban roads have to be aware of all relevant disaster management plans in place, chain of command in case of emergency, steps to be taken and temporary relief and rehabilitation strategies to be employed. Managerial ability for efficient response in clearing key road infrastructure projects, securing unsafe areas, demarcating temporary relief sites for use and ensuring safety, security and basic services before further operations and long term rehabilitation takes place.

In urban areas, they also have to regularly interact with other departments such as traffic police, utilities, transport corporations, metro rail authorities. It is essential that these functionaries:

- are acquainted with disaster management plans by NDMA, emergency transport corridors, staging areas and temporary relief sites

- are acquainted with best national/international practices;
- can effectively follow principles of disaster management, follow chain of command and oversee the tasks entrusted further to relief groups;
- are sensitive to concerns and needs of road users and local communities served by the road, especially vulnerable groups including women, senior citizens, persons with disabilities and reduced mobility;

The following areas need focused attention for capacity building and preparation of a guide:

- Understanding of disaster management plans in place
- Continued education and training for transport planners, government agencies on updated response strategies
- Information dissemination to the public in times of disaster
- Preparation of a guide for local persons giving a broad outline of issues to be addressed and why the information required is necessary and emergency response strategies in place to avoid chaos and confusion resulting in further problems.
- Preparation of a guide for transport professionals, disaster response teams and local agencies that explains in greater detail what information is required, and how to go about preparing and presenting it. It will help them to instruct other consultants to carry out work accordingly.

Issues to be addressed include:

- Safety from impact of building/tree/systems collage and/or breakage
- Removal and/or salvage of debris, felled trees, damage and existing facilities and resources
- Security of vulnerable user groups
- Universal accessibility to all basic emergency services and facilities and rehabilitation thereafter
- Health and Sanitation

Sufficient information dissemination is key, for all groups- disaster preparedness teams, emergency relief workers, transport professional, sub consultants employed in rehabilitation efforts and local citizen groups - what each group should know and why it is crucial.

18.7.5 *Transport Planning Level*

a. Ensure that disaster resilience is an objective while planning for transport systems. This will enable construction of infrastructure that is resilient to disaster.

b. Include disaster response as part of Transportation Planning. Consider the range of possible disasters and stresses on the transport system, and consider the possible solutions.

c. Promote multi-modal transport including non-motorized modes. This will have the following benefits:

   i. Reduction in traffic density and the need to build large number of roads which form obstacles to flood flow and exacerbate disasters;

   - ii. Reduction in the scale of the exposure and vulnerability of the transport sector (and the people and businesses that rely on them) to disasters;
   - iii. Provision of resilient forms of transport in an emergency (walking and cycling).

18.7.6 *Project Design Level*

a. Issue standards and guidelines on project identification and preparation procedures
   - i. Develop appraisal models which evaluate and prioritize the costs and benefits of various project options and also measure the cost of infrastructure damage, failure and service delays from multiple natural hazards, and the benefits of long-term resilience.
   - ii. Ensure that project feasibility reports include an assessment of the impact of disasters on road and transport infrastructure.
   - iii. Use Environment Impact Assessment (EIA) as a tool for main streaming disaster resilience into transport infrastructure by addressing the impact of natural hazards on infrastructure
   - iv. Ensure engagement of the community and the emergency response teams in the project design, planning and implementation.

b. Generate, collect, exchange and disseminate information:
   - i. Improve and revisit on a regular basis the collection of data on natural hazards and the modelling and analysis of this data.
   - ii. Introduce standard formats and reporting standards for monitoring and collecting data pre and post disaster
   - iii. Conduct regular risk assessments and audits for infrastructure assets to collect information on their condition and reliability.
   - iv. Improve knowledge sharing between road owning and transportation agencies, climatologists, scientists, community and other concerned stakeholders.
   - v. Keep records of past weather events and create harmonised data sharing mechanisms through a GIS system.

c. Expertise:
   - i. Capacity building for officials and civil servants- on resilience in transport and to train them to conduct assessments, use revised project screening and monitoring tools, and develop action plans. Core areas for training include: spatial planning, risk analysis, knowledge of mitigation strategies and protective measures, partnership building and networking, collecting, storing and sharing information etc.
   - ii. Engineering skills base- Improve the development skills base among engineering staff, consultants as well as management supervision skills
   - iii. Communities-Increase awareness and learning in communities around hazard-affected areas to ensure early detection of problems and inefficiencies, as well as increase their ownership of the operations and maintenance of the infrastructure.
   - iv. Develop effective ways to maintain information and communication systems among transport system managers, staff and users under normal and extreme

conditions (Operations). Develop ways to communicate with residents and travellers under emergency conditions.

d. Technical- Planning and Design of road infrastructure:

   i. Resilience is shown to be increased either by:
      - Designing the infrastructure itself to be more robust;
      - Designing for safe failure or flexibility;
      - Increasing the robustness of protection works; or
      - Separating the infrastructure from the risk or hazard.

   ii. Design transportation facilities to withstand extreme conditions (earthquakes, storms, etc.).

e. Operations and maintenance:

   i. Maintenance: It is required to maintain the condition of transport infrastructure-culverts; canals; removal of sedimentation; control of vegetation; slopes; and repair of edge; shoulders; potholes; and cracks. The following aspects should be incorporated as a part of the routine infrastructure maintenance practice of the city:
      - Effectively using local resources, particularly human resources, locally appropriate materials, and locally available and low-cost equipment;
      - Nationally coordinated program with consistent standards and an ongoing program of training, retraining;
      - Equipping maintenance crews with non-destructive testing and sensing devices to locate and analyse problems.

   ii. Inspection: Regular and detailed inspection is required to underpin the maintenance and assess whether specific repair works are needed.

18.8 Guidelines for Disaster Response

The period during and immediately after a disaster involves evacuating people, restoring critical lifeline routes, providing basic access and mobility and repairs to damaged infrastructure. This section includes the plans and assessments that must be arranged before a disaster strikes to enable the government to deploy the necessary equipment, personnel, transitional traffic measures, etc. and resume functionality as quickly as possible.

A survey of the damage to be undertaken within the broad extent of surviving features, and a review of salvageable materials and property along with estimation of costs within a defined time frame.

Temporary relief efforts include-

- Identifying and creating areas for the displaced persons to take shelter and avail of facilities including food, toilets, bathing areas and storage areas.
- These spaces, identified in the disaster preparedness stage, may include open fields, maidans, and public buildings such as schools, health centres and community centres which are identified as safe by the authorities for short term rehabilitation.

- Safety, security, accessibility, health and sanitation concerns of all groups including persons with reduced mobility such as senior citizens; families with young children; unescorted children; persons with temporary ailments, medical conditions and hidden diseases; pregnant women; persons with diverse disabilities and people with communication problems (including different linguistic and ethnic groups like migrants, tourists etc.)

Aims of rehabilitation as a whole needs to be agreed upon, including extent of repair, relief and rehabilitation; and an outline scheme set in place before detailed proposals are made and employed.

This will be based on –

- Complexity of place and damage assessment
- Scale of damage
- Scale and complexity of repair task
- Availability of records
- Considerations of access, health and safety

18.8.1 *Guidelines*

a. Prioritise and categorise lifeline routes

Identify and prioritise the transportation networks essential for regional and national mobility beforehand. These are the routes that will aid in evacuation and maintaining basic transportation services.

i. Identify and categorise lifeline networks through a risk-assessment based on criteria determined by stakeholders and consideration of economic, environmental and social impacts.

ii. Conduct audits of these networks to assess performance during both expected and extreme disaster scenarios to help with response planning.

iii. Convey this information in advance to the general public, agencies, utilities and emergency service providers.

iv. Develop plans to provide basic mobility under all conditions. Insure that transport planning takes into account people with special needs (persons with disabilities, low incomes, inability to speak the local language, etc.). Work with community organizations to identify their needs and maintain effective communications with vulnerable groups.

b. Inventory Assets and Assess Capacity

i. Conduct regular reviews of airports and other terminals like ports in the region in the event of lack of access during disaster or increased demand for services. Maintain information on their characteristics and requirements in the event of an emergency.

ii. Create inventory of key transit assets like buses, vans, fuel supplies, communications equipment, repair facilities and key aspects of the assets like construction type, year built, footprints etc.

c. Collaboration across multiple jurisdictions, modes, infrastructure systems and actors
   i. Transport management centres can act as the nerve centres for monitoring traffic, emergency response, co-ordination and travel advisories. These can also act as information dissemination centres during a disaster and have an overview of all emergency preparedness issues.

d. Contingency plans and transition traffic measures
   i. Prepare contingency plans and transition traffic measures to identify alternate routes in the case of an emergency, particularly to major logistic facilities vulnerable to closure such as arterial roads, airports etc. This should include an assessment of where the most vulnerable and at risk people are located and how they should be evacuated.
   ii. Transition traffic measures include:
   – Add extra bus services, maximising the capacity and flexibility of other vehicles.
   – Establish emergency reserve bus fleets effective during an emergency.
   – Implement high-occupancy vehicle requirements.
   – Locate emergency park-and-ride location in advance and draft websites and maps for circulation.
   – Provide for bikes and pedestrians facilities during an emergency to increase the transport system's resilience.
   – Introduce traffic measures to prevent further damage to infrastructure materials.

e. Regular monitoring and review of emergency processes- Identify problems and inefficiencies in the existing system by regularly monitoring and review of processes through a multi-stakeholder team. This will also help in creating response models.

f. Expertise: Build capacity of the emergency staff by conducting training. Regular training exercises should be conducted to identify weak links and ensure that they are resolved.

g. Technical planning, design, operations and maintenance
   i. **Early warning systems:** Create early-warning systems. They take a variety of forms, from both the technologically advanced to relatively simpler community-based systems.
   ii. **Emergency Repair Works:** It is important for emergency repair works to get the right balance between taking immediate action and choosing the correct solutions with the longer-term recovery process and future resilience in mind.
   iii. **Disaster waste recovery:** Waste can be used to fill holes/soft spots and lower grade road construction. Concrete is often the most widely available waste material, but other materials that can also be effectively used are brick, stone, and gravel.

18.9 Guidelines for Restoration Measures (disaster recovery phase)

Reconstruction of transport infrastructure involves the repair of critical infrastructure to a basic state of functionality sufficient to allow recovery, followed by the reconstruction of infrastructure. Aspects to take into account following a disaster:

- Infrastructure assessment- assessment of infrastructure immediately post-disaster to consider the performance of the systems, causes of failure
- Infrastructure performance analysis – comparison of the performance of the system in the event as compared to predicted performance during construction

18.9.1 *Guidelines*

a. Cross-agency reconstruction agencies are required to coordinate data sharing, speed assistance, maximize efficient use of funds, and coordinate and harmonize the reconstruction process.

b. Infrastructure guidelines can be helpful during the reconstruction process to guide repair and replacement decisions. However, there also needs to be a mechanism in place to consider alternatives to the prescribed design standards.

c. Pre-disaster contracting frameworks involve establishing long-term framework agreements between the client and contractors, consultants and suppliers, which enables rapid mobilization, effective risk sharing and collaborative working. Ultimately, this saves time, cost, and resources and lays the foundation for more resilient infrastructure.

d. During reconstruction, a clear monitoring and evaluation plan is critical. Progress must be monitored on a monthly basis and reconstruction programs need to react in real time to fast-changing situations on the ground. An overarching Results Framework can harmonize and integrate strategic priorities by measuring intermediate outcomes. Appropriate performance indicators should also be selected that can usefully measure actual results against expected results. Performance evaluation task forces can also be established after a disaster to assess why infrastructure failed so that lessons are learnt during the reconstruction process.

For details refer National Policy on Disaster Management, NDMA

Two case studies are given- one from India and another from Japan to highlight the disaster effect and disaster mitigation strategies that can be useful.

18.10 Case Studies

18.10.1 *Chennai Floods (December, 2015)*

The disaster affected the Coromandel Coast region of the South Indian states of Tamil Nadu and Andhra Pradesh, and the union territory of Puducherry, with Tamil Nadu and the city of Chennai particularly hard-hit. More than 500 people were killed and over 18 lakh (1.8 million) people were displaced. With estimates of damages and losses ranging from nearly Rs.200 billion (US$3 billion) to over 1 trillion (US$15 billion), the floods were the costliest to have occurred in 2015, and were among the costliest natural disasters of the year.

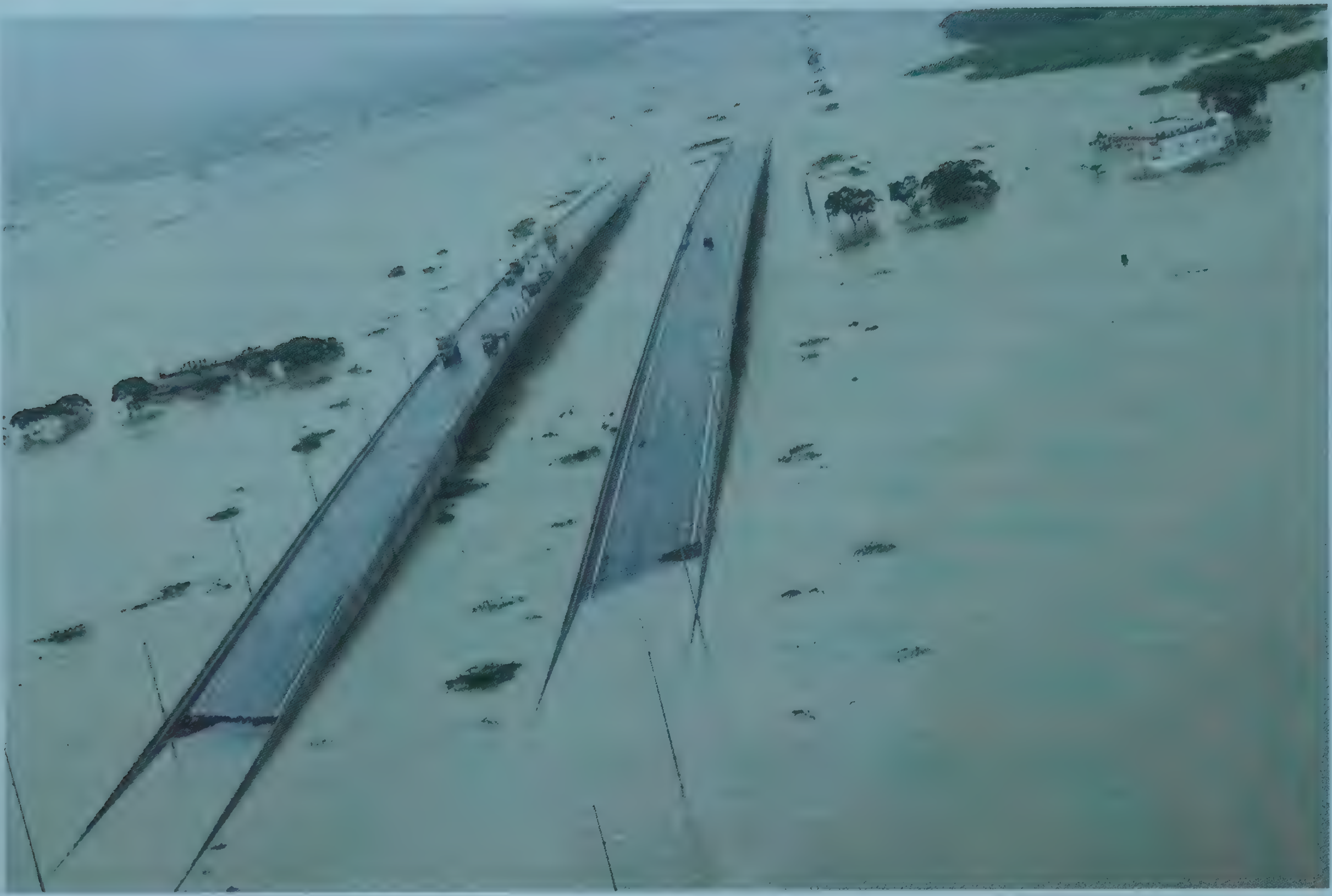


Fig. 18.2 Flooding in Chennai (2015), Source: Indian Air Force

a. Possible causes of flooding:

   i. **Natural Geography:** The city is spread across a low-lying area and is flat like a pancake. The average elevation of the city is only about 6.7 meters above mean sea level.

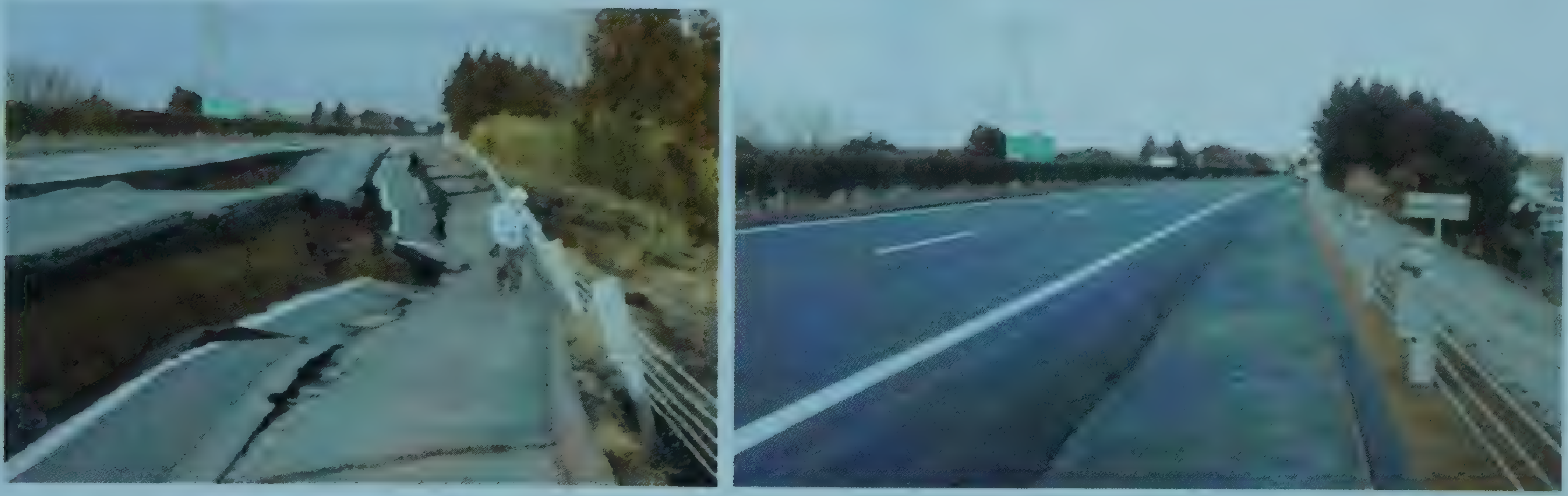
   ii. **Sewage Infrastructure:** The sewage system in Chennai was originally designed for a population of 0.65 million at 114 litres per capita per day of water supply; it was further modified during 1989-1991, but is now much below the required capacity. A study by the National Institute of Disaster Management (NIDM) noted. It has been told that the city has only 855 km of storm drains against 2,847 km of urban roads. (with reference to reports of NIDM)

   iii. **Ponds and Pavements:** It hasn't helped that the city's network of about 650 water bodies including big lakes, ponds and storage tanks has been destroyed. For instance, the total area of 19 major lakes in the city has nearly halved from 1,130 hectares to about 645 hectares. This has meant that the overall capacity of water bodies in the city to contain excess rain water has reduced.Together with an increase in impermeable surfaces such as paved roads and other construction, the peak flow or, the maximum instantaneous discharge of water in some areas has increased by 89% between 1997 and 2001.

   iv. **Devastating of Marsh Land:** The Pallikaranai marshland, 20km South of the city centre that was around 5,000 hectares (ha) at the time of Independence got reduced to almost 600 ha around 2010-11.

18.10.2 *The Great East Japan Earthquake and Tsunami (March, 2011)*

Introduction: The 2011 earthquake, off the Pacific coast of Tōhoku, was a magnitude 9.0 undersea megathrust earthquake off the coast of Japan. It was the most powerful earthquake ever recorded to have hit Japan, and the fourth most powerful earthquake in the world since modern record-keeping began in 1900. The earthquake triggered powerful tsunami waves that reached heights of up to 40.5 metres. Along with a string of nuclear accidents, a Japanese National Police Agency report confirmed 15,894 deaths and 6,152 injured. Besides, 2,562 people were reported missing across twenty prefectures, as well as 228,863 people living away from their home in either temporary housing or due to permanent relocation.



Soon after the earthquake, on March 11, 2011

Fully restored, on March 17, 2011

Fig. 18.3 Image Source: Yoshitaka Motoda

Ordinary vehicles were shut out of the road on 15 expressway routes and 69 segments of roads managed by the national government. The strategy for road repair is useful to study: (**Fig. 18.3**). **Fig. 18.4** gives an idea of Comb Foundation for post disaster repairs and restoration of road network.

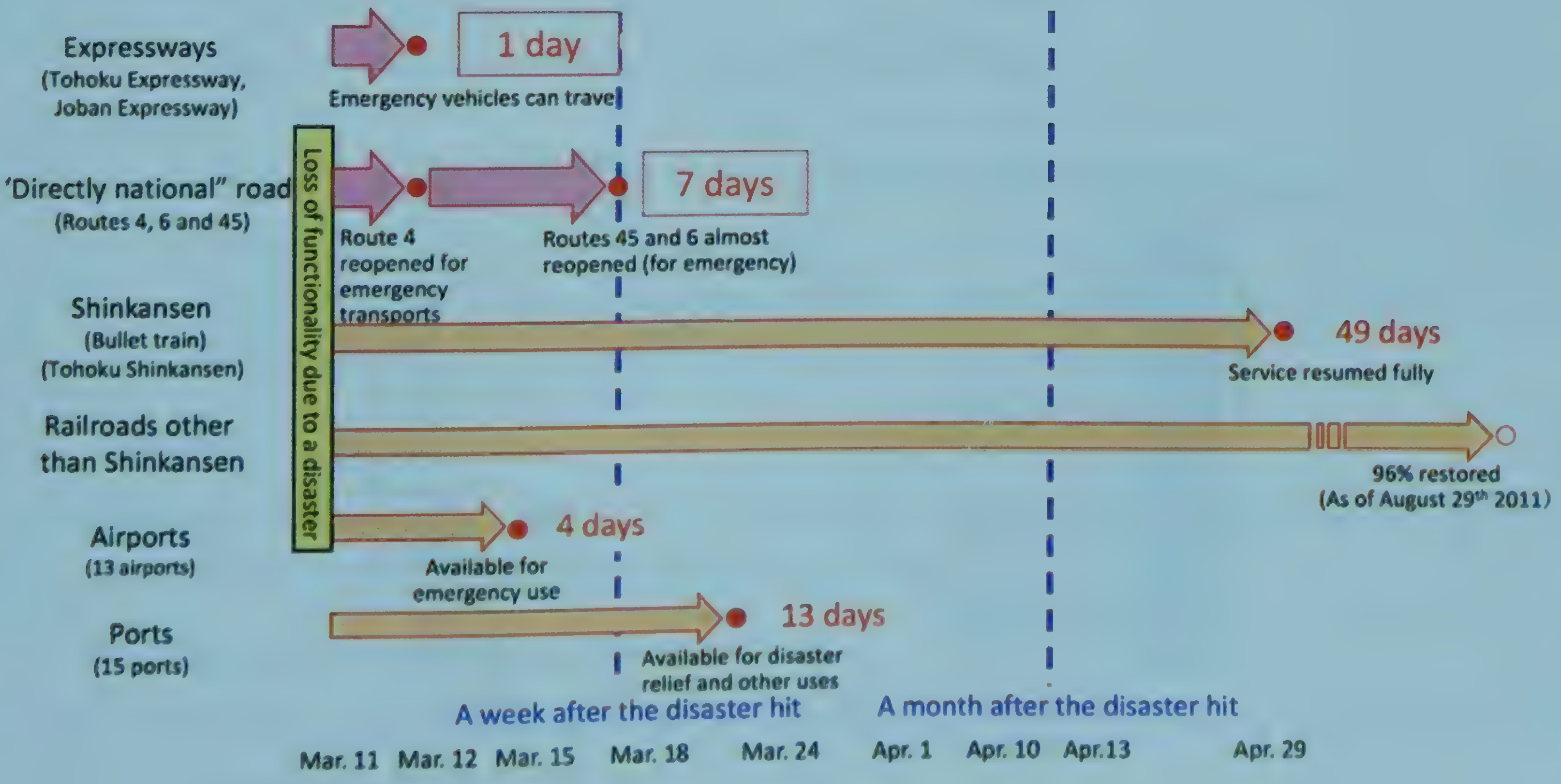
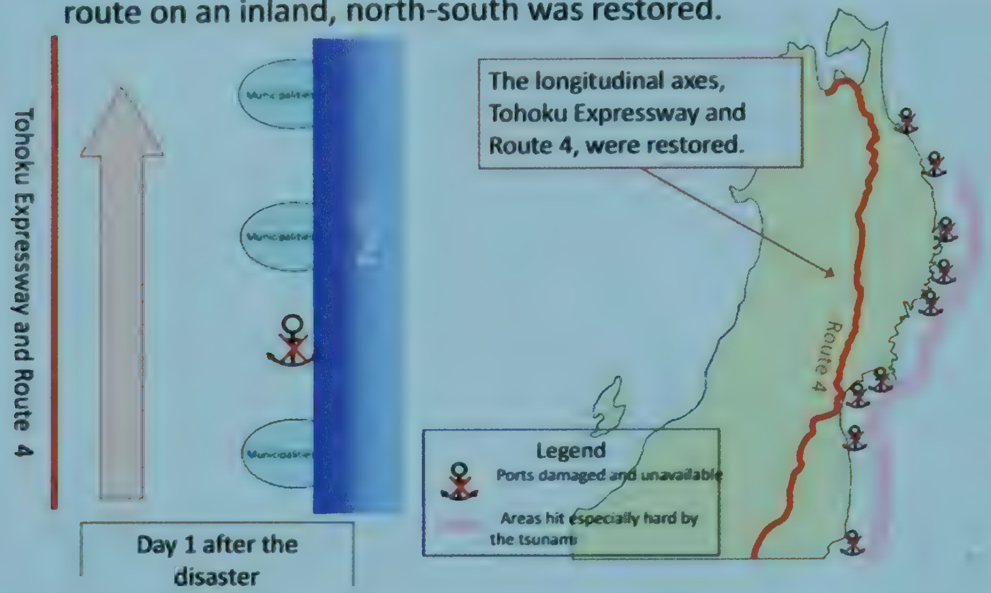


Fig. 18.4 Image Source: Toshitaka Motoda

"Comb Formation" - 1

1) Day after the earthquake (March 12)

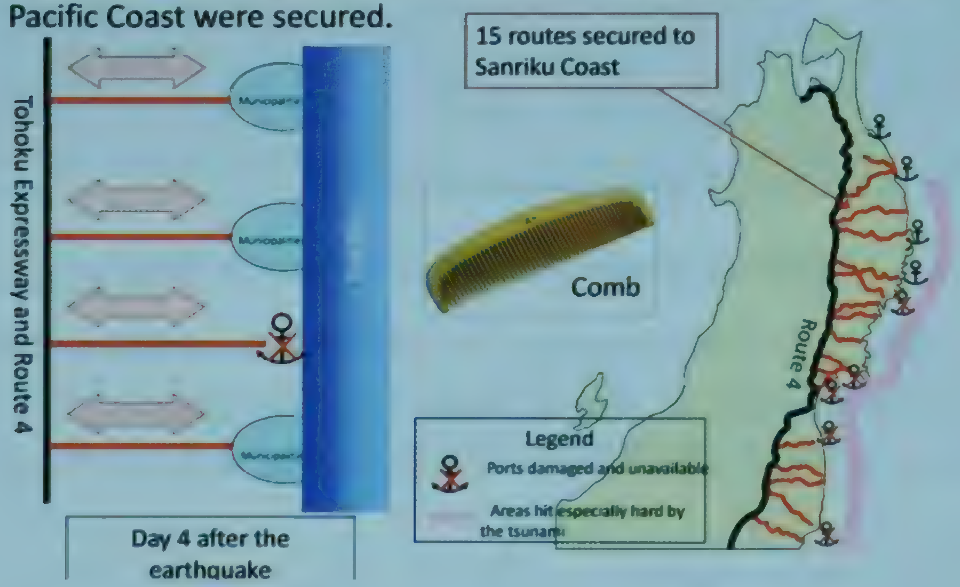
- First, on the day after the earthquake, the emergency transport route on an inland, north-south was restored.


Tohoku Expressway and Route 4
Day 1 after the disaster
The longitudinal axes, Tohoku Expressway and Route 4, were restored.
Route 4
Legend
Ports damaged and unavailable
Areas hit especially hard by the tsunami

"Comb Formation" - 2

2) Day 4 after the earthquake (March 15)

- Next, multiple transport routes between the inland axes and the Pacific Coast were secured.


Tohoku Expressway and Route 4
Day 4 after the earthquake
15 routes secured to Sanriku Coast
Comb
Route 4
Legend
Ports damaged and unavailable
Areas hit especially hard by the tsunami

"Comb Formation" - 3

3) A week after the earthquake (March 18)

- Finally, the north-south roads along the Pacific Coast were restored.

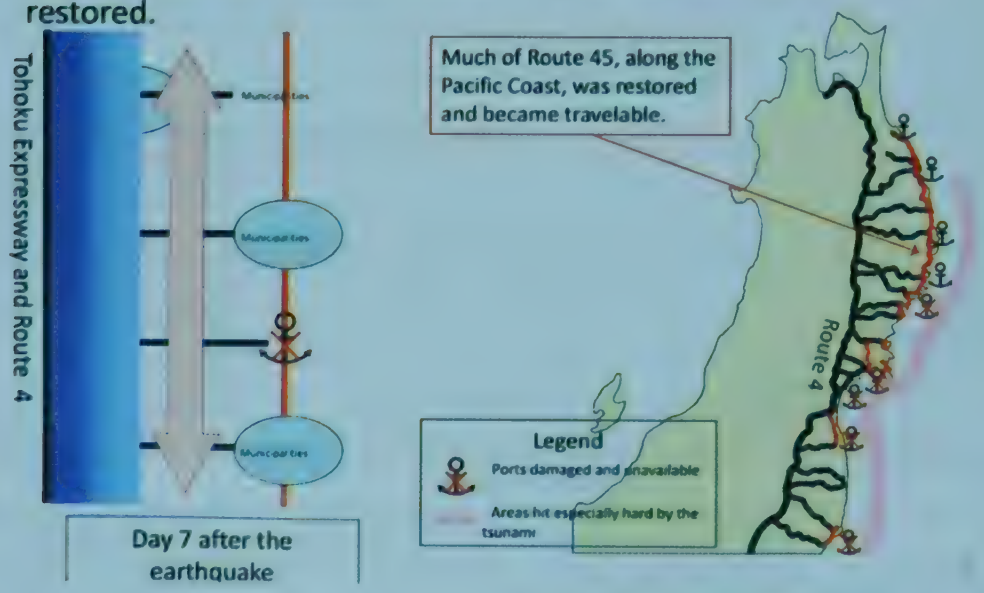

Tohoku Expressway and Route 4
Day 7 after the earthquake
Much of Route 45, along the Pacific Coast, was restored and became travelable.
Route 4
Legend
Ports damaged and unavailable
Areas hit especially hard by the tsunami

Fig. 18.5 Comb Formation Image Source: Yoshitaka Motoda

CHAPTER 19

PARKING MANAGEMENT

19.1 Introduction

Growth of population, urbanization and income levels has led to increased ownership of personalized cars and two-wheelers. In cities, this has led to huge demand for parking facilities and consequent need for meeting the demand as also managing the demand. Guidance on planning, designing and managing public on-street and off-street parking facilities is given here. This chapter draws heavily from IRC "Guidelines for Parking Facilities in Urban Areas" IRC:SP:12. Broad objectives of parking management are:

- Provide relief from congestion for improved environment
- Reduce parking demand through supply restraint measures and pricing strategies

19.2 Key Guiding Principles

The key guiding principles are:

- Achieve optimum utilization of available parking spaces and their increased turn over.
- Accommodate long term parking on off-street parking lots.
- Parking fee to reflect value of land and to act as a demand management tool. Treat parking as a consumer commodity.
- Adequate parking space for public transport vehicles and non-motorized transport.
- Increased use of information and communication technology to inform the vehicles users about the slots availability in parking lots.

19.3 Parking Strategies for Different Types of Vehicles

i) Cars

- Pricing of parking facilities.
- Rate of parking fee based on time, location and use.

ii) Buses

- Public facilities for parking buses and commercial vehicles on chargeable basis.
- Underside of flyovers, overpasses and underpasses should not be permitted for parking of any type of transport vehicle to avoid fire hazard.

iv) Trucks

Parking facility for loading and unloading of trucks at commercial locations like designated markets, godowns, industrial areas etc.

v) Intermediate Public Transport

- Priority and subsidized parking for intermediate public transport like taxis, auto-rickshaws, feeder vans etc. at;

- Bus terminals and Bus stops
- All Metro/mono railway stations
- Near important building complexes
- Non-Motorized Transport (NMT) like cycle rickshaws, cycles, vendor carts, cycle carts etc. treated at par with IPT for parking facilities.

v) **Emergency Vehicles**

All types of emergency vehicles such as ambulances, fire engines, police vehicles could be parked on all categories of roads at designated and appropriate locations. They can be demarcated on ground with proper signage.

19.4 Types of Parking Facilities

Parking facilities are divided into three main categories:

- On-Street Parking
- Off-Street Parking
- Special Parking

i) **On-Street Parking**

On-street parking facility is usually at the kerb side (edge of carriageway). Parking of vehicles can be parallel, perpendicular or angular with respect to the carriageway. However, parallel parking should be preferred.

ii) **Off-Street Parking**

This facility can be in the form of surface parking lot or car park structure either underground or elevated. Access to such facilities could be for either public or private use. These parking lots can be managed by municipality or by private or semi-public enterprises. Proper lighting arrangements need to be ensured, especially for underground and elevated parking facilities.

iii) **Special Parking**

Special parking facilities comprise automated parking and semi-automatic parking systems. For details, refer IRC:SP:12

19.5 Parking Space Requirements

Parking space requirements for different types of vehicles are given in **Table 19.1.**

Table 19.1 Parking Space Requirement

Vehicle Type	Space Required
Car	20-36 sq. m.
Buses and Trucks	55-60 sq. m
Three Wheelers	10-15 sq. m

Parking norms are generally prescribed in terms of Equivalent Car Spaces (ECS). **Table 19.2** gives ECS values for different types of vehicles

Table 19.2 Equivalent Car Spaces (ECS)

Vehicle Type	ECS
Cars	1.00
Two Wheelers	0.25
Three Wheelers	0.50
Cycles	0.10
Buses and Trucks	2.50
Cycle Rickshaw	0.80

Source: IRC:SP:12, URDPFI Guidelines and MoUD 2014.

19.6 Parking Layouts

Parking layouts are given in IRC:SP:12-2015. For ease of reference, these are reproduced here. **Figs. 19.1** to **19.5**.

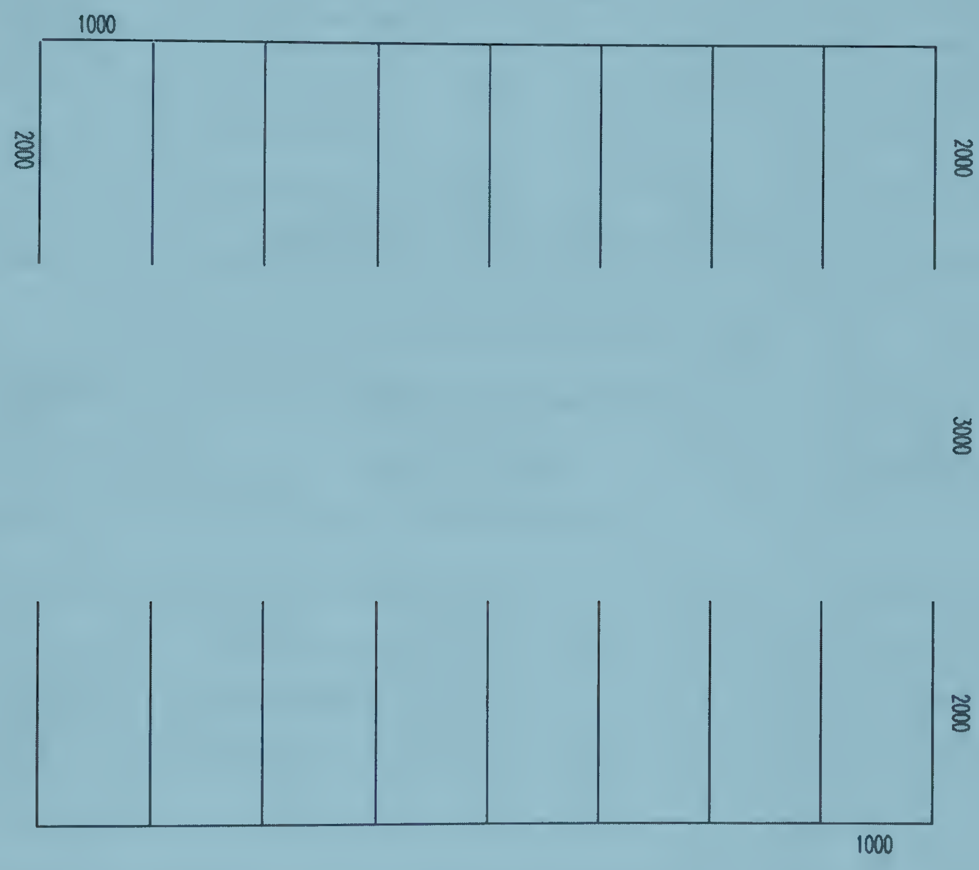

1000
2000
2000
3000
2000
1000

Fig. 19.1 Parking Layout Design for Two Wheelers

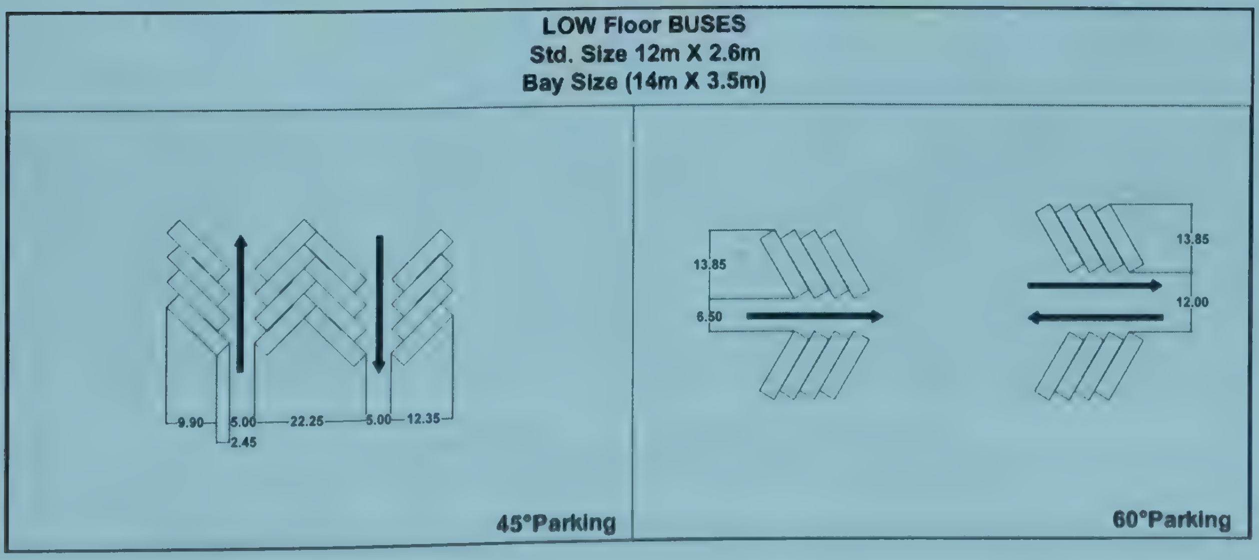

LOW Floor BUSES
Std. Size 12m X 2.6m
Bay Size (14m X 3.5m)
9.90
5.00
2.45
22.25
5.00
12.35
45°Parking
13.85
6.50
13.85
12.00
60°Parking

Fig. 19.2 Parking Layout Design for Low Floor Buses

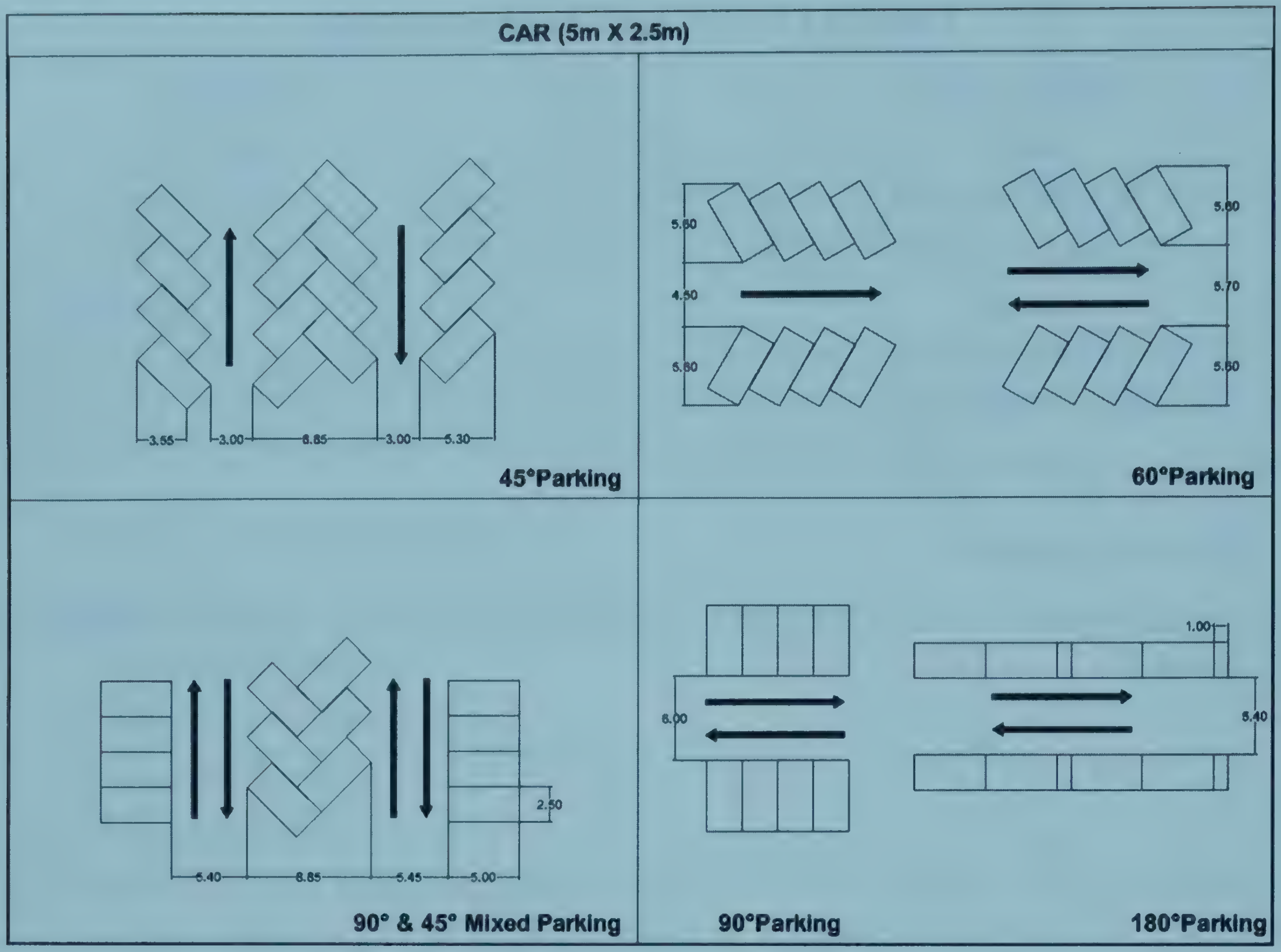

CAR (5m X 2.5m)
3.55
3.00
6.85
3.00
5.30
45°Parking
5.60
4.50
5.60
5.60
5.70
5.60
60°Parking
2.50
5.40
6.85
5.45
5.00
90° & 45° Mixed Parking
6.00
90°Parking
1.00
5.40
180°Parking

Fig. 19.3 Parking Layout Design for Cars

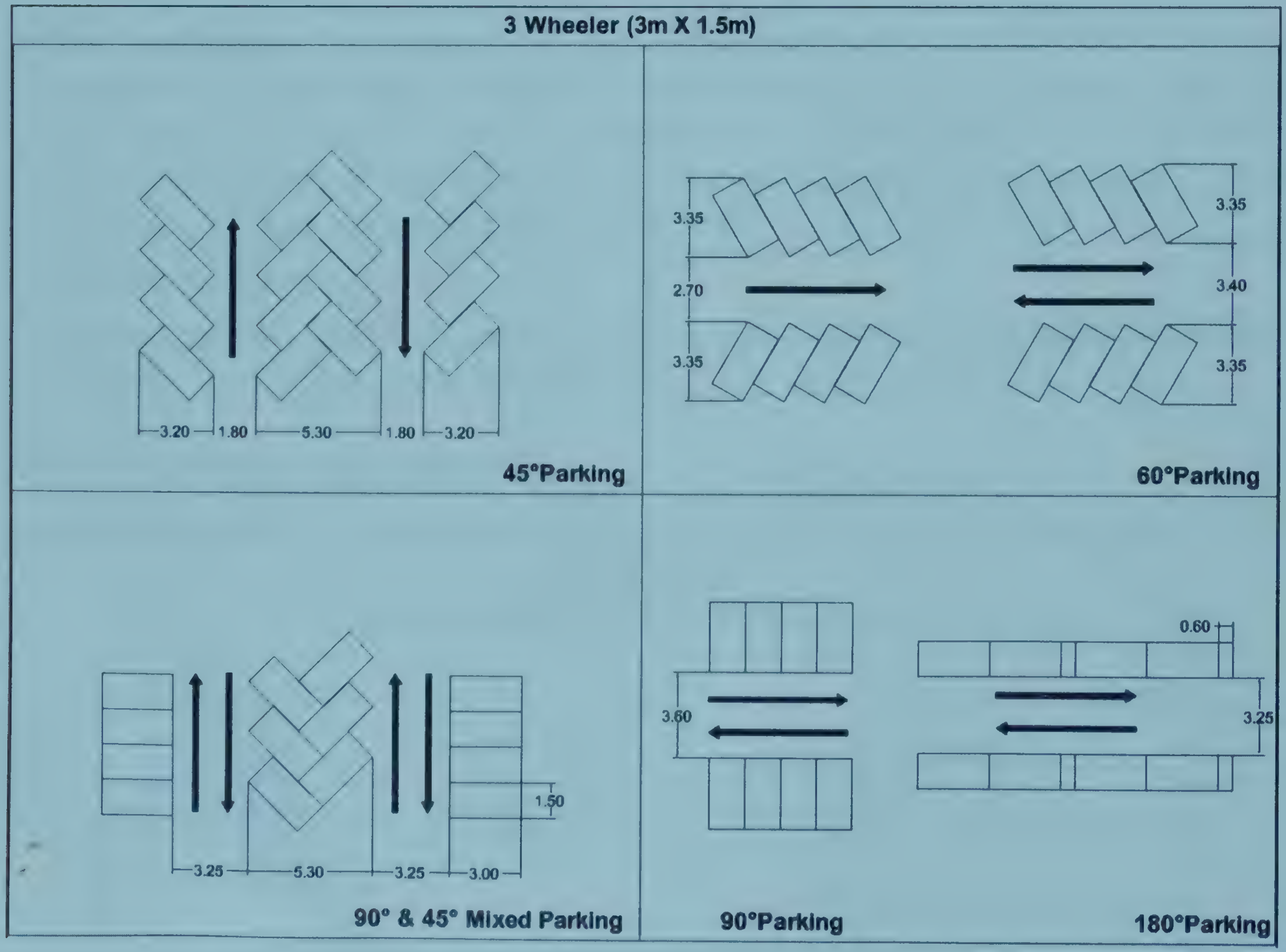

3 Wheeler (3m X 1.5m)
3.20
1.80
5.30
1.80
3.20
45°Parking
3.35
2.70
3.35
3.35
3.40
3.35
60°Parking
1.50
3.25
5.30
3.25
3.00
90° & 45° Mixed Parking
3.60
90°Parking
0.60
3.25
180°Parking

Fig. 19.4 Parking Layout Design for Three Wheelers

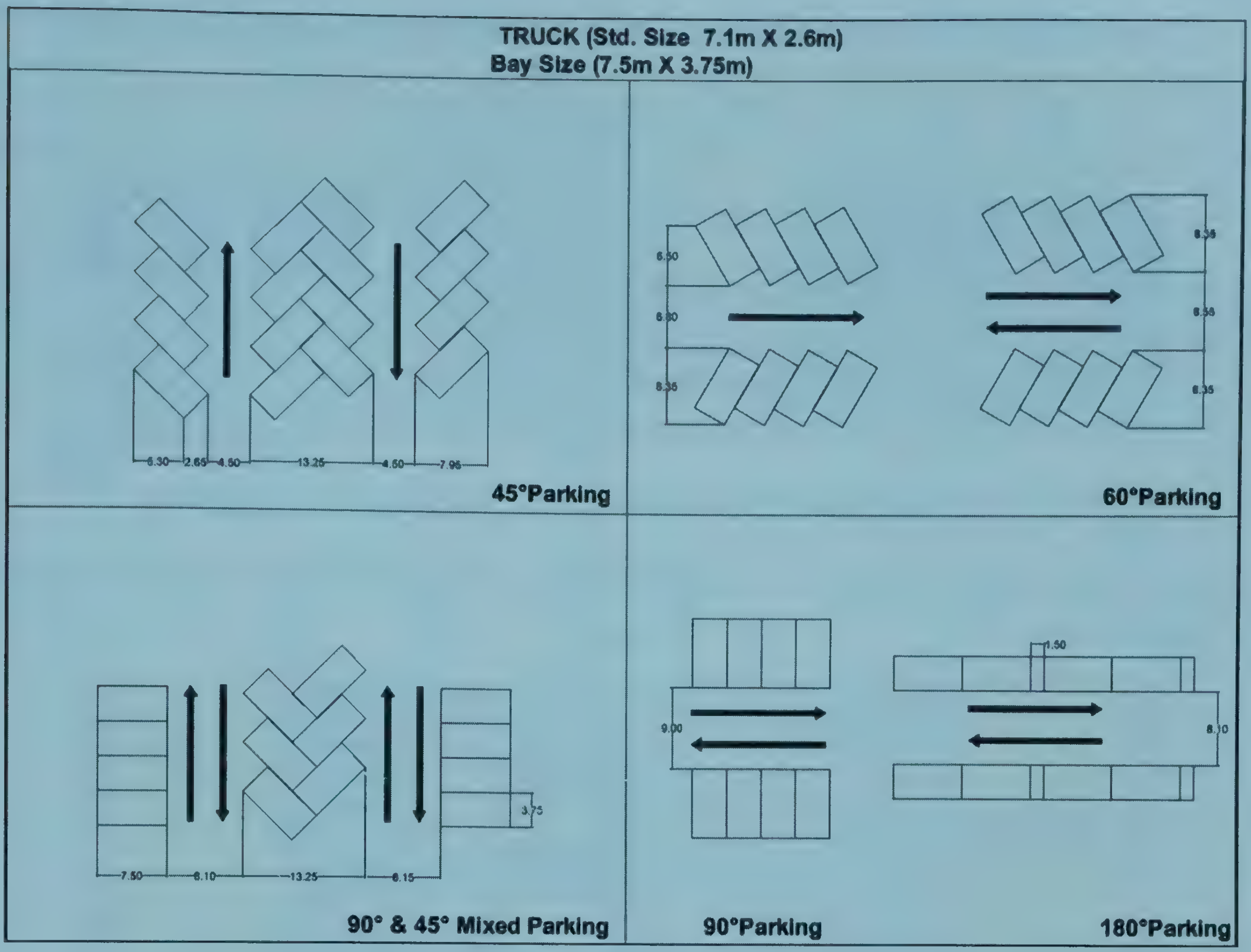

TRUCK (Std. Size 7.1m X 2.6m)
Bay Size (7.5m X 3.75m)
6.30
2.65
4.50
13.25
4.50
7.95
45°Parking
6.50
6.80
6.35
6.35
6.55
6.35
60°Parking
3.75
7.50
6.10
13.25
6.15
90° & 45° Mixed Parking
9.00
90°Parking
1.50
6.10
180°Parking

Fig. 19.5 Parking Layout Design for Trucks

19.7 Parking Design Considerations

On-street parking is not desirable on arterial roads to provide smooth traffic flow. On-street parking may be provided on collector and local streets.

On-street parking space should be provided as per IRC:SP:12. Each parking bay should be clearly defined and marked to avoid haphazard parking and inconvenience to pedestrians and traffic flow. Parking signages should be provided as per IRC:67. Parking should be interrupted by bulb-outs at intervals of 25m maximum (**Fig. 19.6**). Continuous parking discourages people from using footpath.

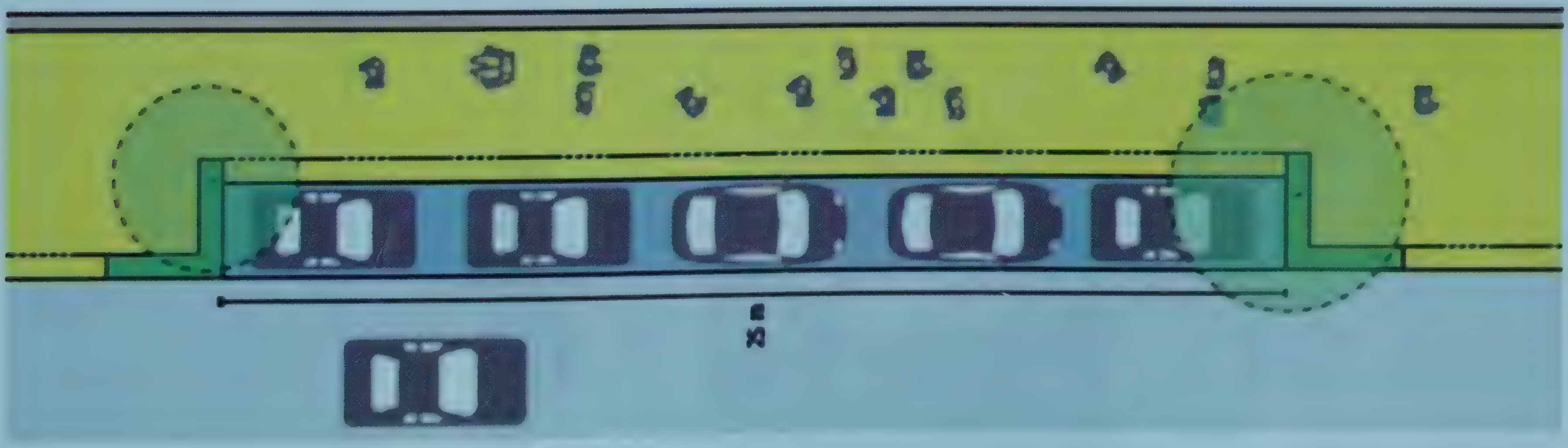


Fig. 19.6 On-Street Parking Planning Detail

Where on-street parking is provided, bulb-outs should be provided at pedestrian crossing for pedestrians' safety and visibility (**Fig. 19.7**).

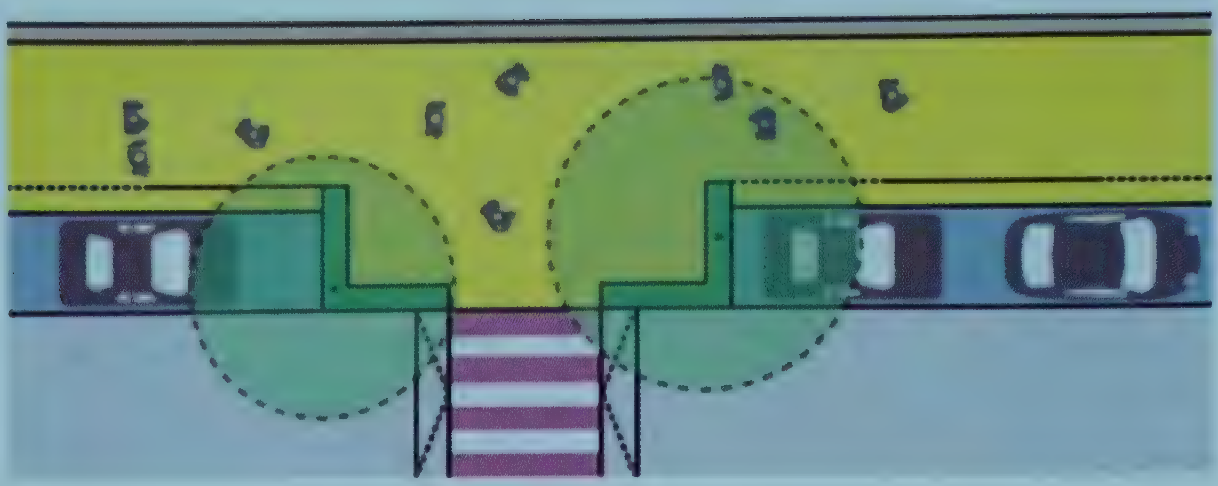


Fig. 19.7 On-Street Parking detail at Pedestrian Crossing

On narrow streets with high density of two-wheeler parking, angular two-wheeler parking may be provided (**Fig. 19.8**).

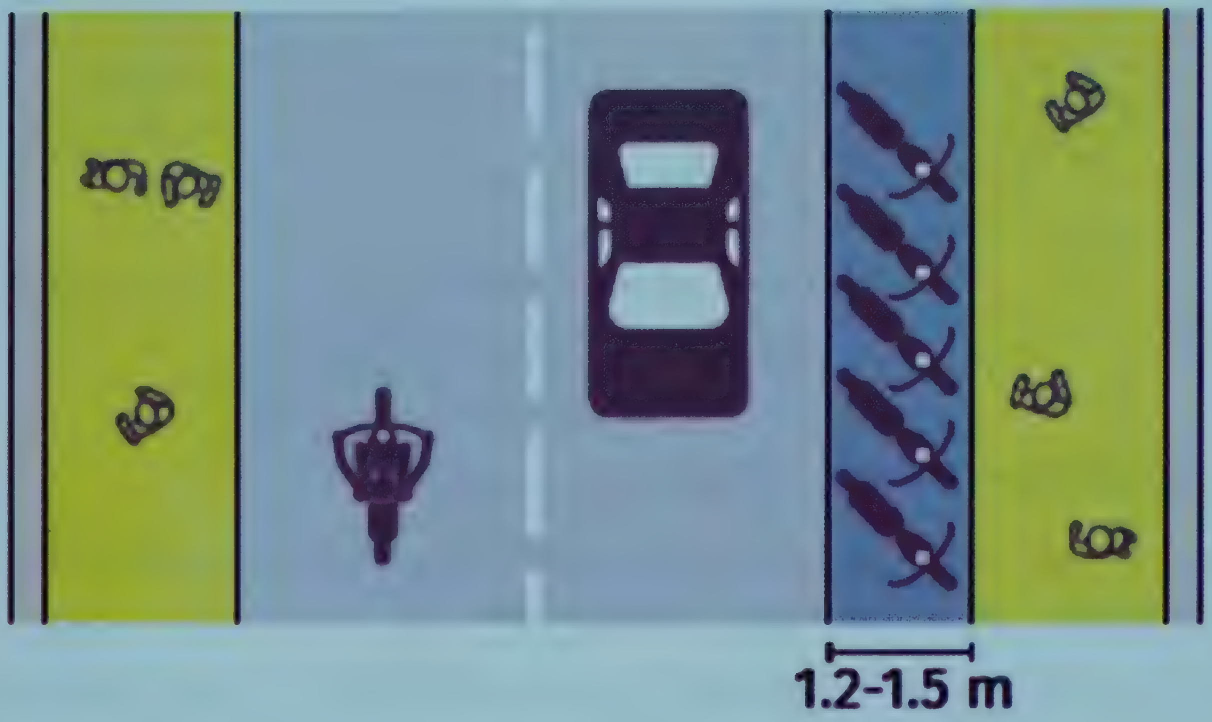


Fig. 19.8 On-Street Parking detail for 2-Wheeler on Narrow Street

A 0.5 meter buffer is recommended along footpath/cycle track edge to ensure that vehicle overhangs do not affect the movement (**Fig. 19.9**).

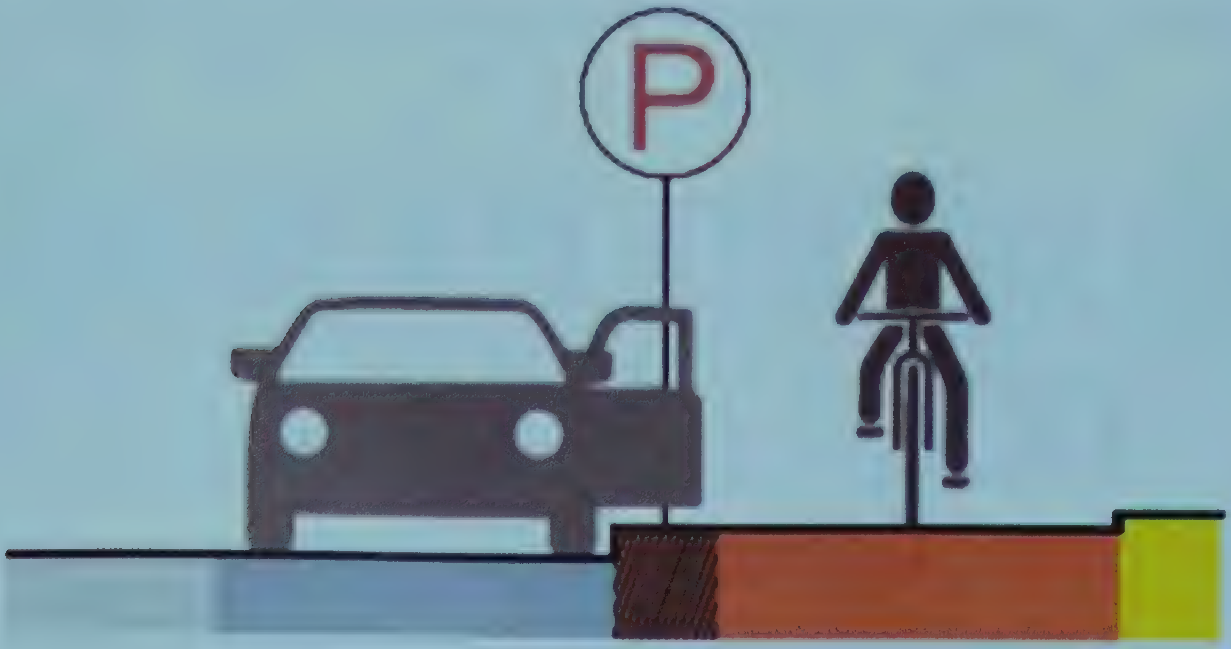


Fig. 19.9 Buffer detail between On-Street Parking and Cycle Track

19.8 Parking for Persons with Disabilities and Reduced Mobility

In order to ensure universal accessibility, it is essential to provide appropriate parking facilities for persons with disabilities and reduced mobility. Following guidelines need to be adopted:

- Provision of sign with the international symbol of accessibility mounted high enough so that it can be seen while a vehicle is parked in the space.
- Boundary of the access aisle must be marked. Two parking spaces may share an access aisle width of aisle, should be 1.2 m (**Fig. 19.10**)

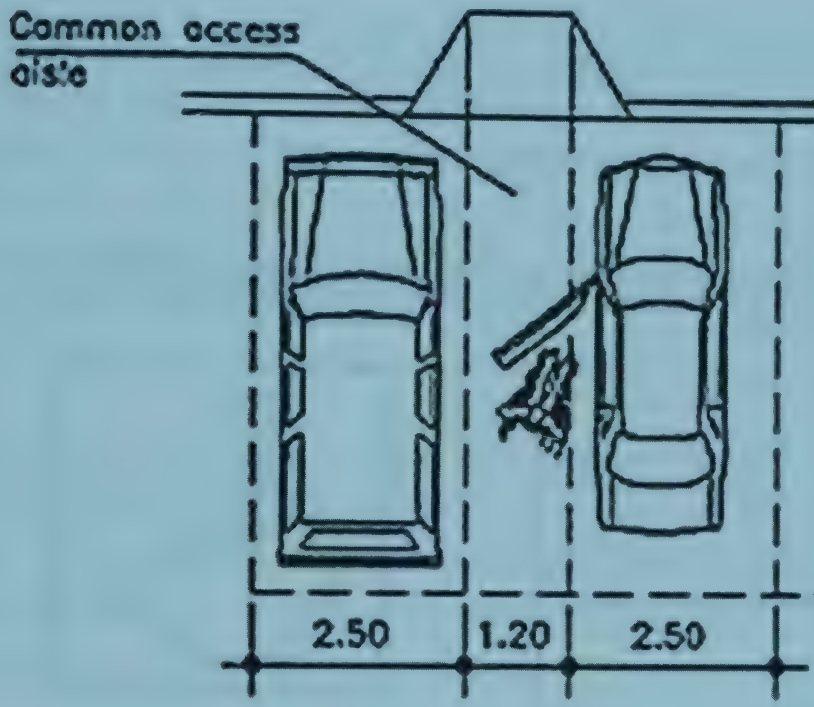


Fig. 19.10 Common Access Aisle

- For parking facilities upto 50 cars, at least one accessible parking space should be provided.
- For parking facilities of 400 spaces, at least 8 accessible parking spaces should be provided.
- The minimum width of parking space shall be 3.60 m. However, recommended width is 3.90 m. (**Fig. 19.11**)

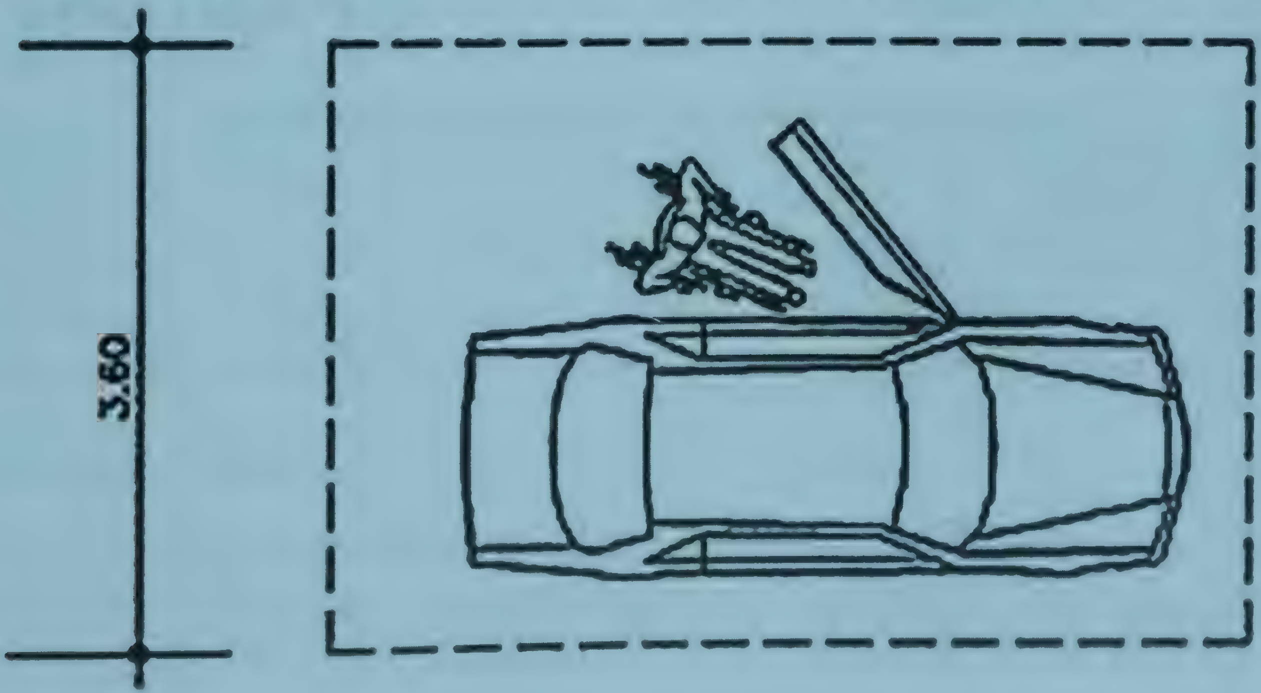


Fig. 19.11 Width of Accessible Parking

- Accessible parking slots should have international symbol of accessibility painted on it on the ground as also on a sign board near it. The colour of the symbol shall be white on a blue background. (**Fig. 19.12**)
- In case of indoor parking, the minimum height clearance is 2.40m.
- For angled parking spaces, the extra space at the end of a row can be used as a parking aisle for disabled persons.
- If a kerb exists, kerb ramps should be provided to link accessible parking spaces to accessible pathways.
- If no kerb exists, textured surface at least 0.60m wide must separate the pathway from the vehicular area; or else bollards should be used. Pre-cast wheelstops can be used to create a passage, at least 0.90m wide.

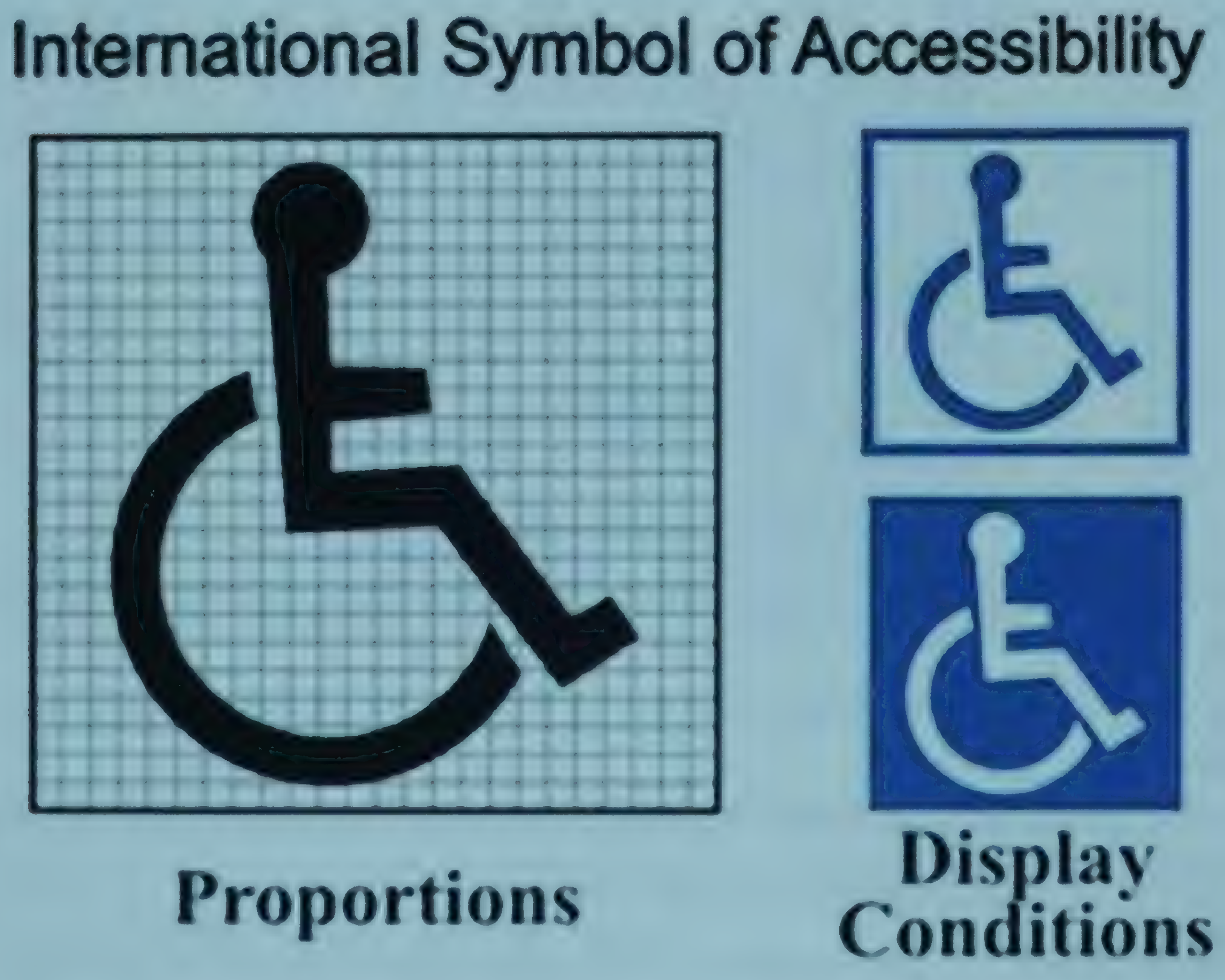


Fig. 19.12 International Symbol of Accessibility

CHAPTER 20

TRANSPORT DEMAND MANAGEMENT

20.1 Introduction

Transport Demand Management (TDM) is a set of actions aimed at managing the demand for on-road travel, particularly single-purpose and low-occupancy travel. Such travel is usually the case when personal motor vehicles are used. TDM interventions are meant to modify travel decisions/travel behaviour (i.e. how, when and where people travel). The objective is to increase the efficiency of the road network and decrease the negative impacts of road transport.

Some TDM interventions are specific to reducing overall travel demand. Others target a certain kind of demand like parking, or a particular period of time (traffic peak hours/days), or a particular location (central business district). Depending on the context in which they are employed, the various strategies comprising of an overall TDM approach can be used singly or in different combinations.

The move towards sustainable transport needs attention on not only supply-side interventions, which focus predominantly on promoting public and non-motorized transport, but also initiate demand-side interventions that stabilize Private Motor Vehicles (PMV) use. Thus, Transport Demand Management (TDM) is a key tool within the sustainable transport toolkit, which aims to regulate and reduce the demand and use of private motor vehicles.

This chapter discusses the key TDM measures, their applicability, benefits as well as challenges in implementation.

20.2 Key principles

TDM measures have been employed in urban contexts to predominantly secure two objectives: (i) to reduce the negative externalities of motorized travel on environmental and social well-being; and (ii) to support local/regional economic goals. Some common characteristics of TDM measures are:

20.2.1 *User Pays Principle*

A key consideration in TDM is the user pays principle. Motorized travel entails such costs as congestion and pollution. While the traveller enjoys the benefits of travel, its costs, however, are usually borne by others as well. The use of urban space should be optimized so that more people benefit from it. TDM measures like parking management and congestion pricing are meant to ensure this for public resources related to transportation facilities and services.

20.2.2 *Sustainable Transport*

Even as the negative externalities are sought to be priced and disincentivized, it is important that use of public resources is more equitable and efficient. The idea of TDM needs to be aligned with sustainability within urban transport planning.

20.2.3 *Being Coordinated and Technology-Enabled*

Successful implementation of TDM measures requires appropriate technology, including Information and Communication Technology (ICT). It does not have to be high-end technology, but one that helps in enhancing the level of service for traffic on the overall network. The current widespread presence and acceptance of ICT-enabled gadgets and services must be capitalised. 'Common Mobility Cards' for all payments within a city's transport system is an example.

On the supply-side, ICT is a useful technology for information integration (over and above or even prior to structural integration) in order to promote inter-modalism among several Public Transport (PT) and Private Shared Mobility (PSM) options. ICT can also facilitate value-additions to the enforcement of TDM measures.

20.2.4 *Being Scientific, Data-Driven and Outcome-Oriented*

TDM measures may include parking management, road pricing, improving PT quality and inter-modalism, integration of PT with NMT infrastructure and with PSM. The more integrated these measures are, the better.

Further, such integration could cut across policies, financial plans, implementation measures and monitoring mechanisms as well. This would also mean that major share of revenue generated from TDM measures may be utilised to fund sustainable transport infrastructure, facilities and services.

TDM measures should be based on scientific analysis of ground data and development of simple models. This is crucial to plan and identify the appropriate measures and their effective implementation.

20.3 Key Transport Demand Management Strategies

The key TDM measures and their implementation aspects can be clubbed into the following categories:

a. Public Transport and Private Shared Mobility
b. Urban road design and parking management
c. Financial incentives and disincentives
d. Transit-Oriented Development
e. Employee TDM measures
f. Freight movement management

These are briefly discussed here.

20.4 Public Transport (PT) and Private Shared Mobility (PSM)

Public Transport (PT) facilitates most medium and long-distance intra-city and inter-urban agglomeration trips. If PSM mode shares (informal auto rickshaws, share autos, private buses, minivans etc.) are also considered, mode share of private motorized vehicles can shrink further to reduce congestion on roads. The usual PT option is city buses or other bus-based services such as express intra-city buses, area-specific shuttle services. Making good quality PT available where it is needed, improving existing PT services should be the next key steps. Side by side, PSM options can be promoted to complement the public transport.

Where, a city's population exceeds a certain number, or if otherwise the local context demands, a Mass Rapid Transport (MRT) system may be needed to move more people, more rapidly, more conveniently over long distances. Then, instituting an MRT option becomes the needed improvement option. Among rail-based options, mention may be made of sub-urban rail, metro rail, light rail transit. Road-based Bus Rapid Transit (BRT) is highly cost-effective and can easily meet quite heavy demand. It can be implemented swiftly, for it uses the existing roads. It can use existing buses if they meet its standards, though it is better to procure state-of-the-art buses. For details, refer IRC:124-2017 on BRT guidelines.

Another option is that of High Occupancy Vehicle (HOV) lanes, which prioritize movement of such vehicles or allow them to jump queues in traffic with the help of dedicated lanes. They can also benefit from priority signalling. This saves time and attendant costs for the passengers and the operators. As more and more low occupancy vehicle users shift to HOVs like city or private buses or even shared car users, this option decreases related congestion and pollution.

20.5 Urban Road Design and Parking Management

20.5.1 *Urban Road Design*

Urban roads and streets are meant to be used by all road users including cyclists, pedestrians and users of hand carts, push carts. In some countries, small-wheeled options like skates, skateboards are quite popular. Wheelchairs and care-givers with prams should be included. The idea is that NMT requirements should be consciously built into physical design. IRC has already developed standards for footpaths (IRC:103), which should be applicable to the construction of footpaths. Where footpaths are needed but they are absent, the starting point has to be re-allocation of road space to provide for them. Post-construction cleanliness and maintenance of footpaths must also be ensured. Chapter 5 brings out the key requirements for pedestrian facilities. Similarly, separate cycle tracks, bicycle parking and ideally, even public bicycle sharing systems should be adequately and appropriately incorporated into urban road design based on assessment of needs. Chapter 6 brings out the key requirements for cycle tracks.

20.5.2 *Parking Management*

A city's sustainable transport relies heavily on availability of parking facilities for all road users, cyclists, motor-cyclists, scooterists, auto rickshaws, taxis, cycle rickshaws, cars, buses and trucks and effective parking management. For details, refer to Chapter 19 on Parking Management and IRC:SP:12 "Guidelines for Parking Facilities in Urban Areas".

20.6 Financial Incentives and Disincentives

The role of public finance, such as finance policies/budgets, in supporting and strengthening sustainable urban transport and land use policies need not be over-emphasized. Implementing sustainable urban transport means and requires that financial policies and budget allocations may be aligned to the priorities in funding sustainable urban transport. Toll is a road pricing tool. Tolls fund includes both, investments already made for road building and ongoing maintenance expenditure. Thus, they are a fee-for-a-service. This is considered fair because not only does it benefit the users, but it also benefits the non-using taxpayers who don't have to pay for a service they do not use.Tolling in India is becoming common in conjunction with private sector participation in capacity augmentation projects on national highways and state highways as also for facilities such as bridges, flyovers, bypasses, etc. For cities, as an example, Singapore's road pricing policies cover different charges for different vehicles. Hybrid and electric vehicles pay lower fees. In Delhi, an Air Ambience Fund has been created by levying a fee at the rate of ₹ 0.25/- per litre on diesel. The fund promotes clean technologies.

20.7 Transit-Oriented Development (TOD)

Developing efficient locations with availability of Public Transport (PT) in close vicinity can also be an effective TDM measure. Also referred to as Transit Oriented Development (TOD), it is essentially an endeavour to match availability of PT with population densities in urban areas. Well planned NMT facilities within such Transit-Oriented Zones (TOZs) brought about by a dense and well-connected urban road network would be a useful measure.

TOD secures its aim of reducing travel distances and travel costs for people by encouraging compactness within itself. Compactness comes about due to the emphasis on NMT infrastructure. Mixed land use can be achieved through setting up facilities for a variety of socio-economic activities within a locality like, residential (for different income groups), commercial (offices as well as retail shops), public services (education and health centres) and public amenities (parks, playgrounds etc.).

20.8 Urban Freight Movement Management

Urban freight is an area requiring more attention of the transport planners and policy makers. Movement of goods is critical to everyday life of citizens and impediments to it can have negative impact on a city's economy and hence on its vitality. It is important to accommodate the movement and delivery of goods into a city's road transportation network. Similarly, goods movement must be flexible and accommodating to the changes in the environment in which it operates.

As more people move to urban areas, their demand for goods also increases. Highly urbanised areas also happen to be the main hubs in global or national freight distribution networks. Moreover, they host terminals, such as, ports/rail yards/airports/truck terminals. Goods need to be moved between and within urban areas. General congestion delays strain goods movement as well as the businesses and consumers involved. Urban freight movement needs to be duly accounted for in planning of the urban road infrastructure and movement needs of freight.

20.9 Employee TDM Measures

Greater coordination among different stakeholders holds greater potential for firmly grounding transport sustainability. Public policy initiatives and regulatory interventions can thus be supported and sometimes even reinforced by what are referred to as Employee TDM measures. These measures include flexi-work-timings implying that not all employees have to be in and out of office at the same time. Some can leave early if they arrive early, while those arriving later would leave later. A practice similar to flexi-work-timings is staggering of work shifts. In this case, not all employees are travelling at the same time. This practice has existed in certain public entities and in private industries in India for quite some time now. This has helped in increasing the duration of peak period for traffic and comparative ease of congestion. Another measure is compressed work week, whereby employees work for fewer days, but for longer hours on work days. Another trend catching up particularly in the private sector and thanks to technological advances like video conferencing etc. is working from home. This has been facilitated to a large extent by the growth of e-commerce as well as e-governance.

Company buses or campus buses is a widely existing practice all over the world and also catching up in India in both the public and private sectors, either fully as a staff welfare measure or on payment basis. Of late, some employers are offering cab services similarly. All such employees oriented TDM measures do help in reducing the strain on existing road network in urban areas.

More and more organizations can thus be encouraged through public programmes and incentivised through financial instruments to ramp up their support to employees' commute by tagging such policies and programmes to a city's sustainable development goals.

20.10 Assessing Impacts of TDM Measures

TDM programs can be evaluated using some of the performance indicators. These indicators can be defined for a particular time such as peak-hour and geographic location such as a particular destination or district. Examples of performance indicators include mode share data on per cent increase in use of public transport, private shared taxis, autos, employee buses, reduction in average trip length, introduction of staggering/flexi working hours.

CHAPTER 21

INTELLIGENT TRANSPORTATION SYSTEM AND TRAFFIC MANAGEMENT

21.1 Introduction

Intelligent Transportation System (ITS) is the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveller knowledge to extend the safety and efficiency of the surface transportation systems (Mathew, 2014). These systems involve vehicles, drivers, passengers, road operators, managers of transport services, all interacting with each other and the surroundings, and linking with the advanced infrastructure systems to boost the security and capacity of road systems. In the leading nations in the world, ITS has brought vital improvements in transportation performance, as well as reduced congestion and pollution besides enhanced safety, energy efficiency and traveller convenience. This chapter has drawn heavily from IRC:SP:110 "Application of Intelligent Transport System For Urban Roads".

21.2 Challenges in the Traffic Management and Road Safety

The main traffic challenges being faced in major cities are traffic congestion, traffic accidents and vehicular emissions.

i. **Traffic Congestion:** Congestion in large urban agglomerations is significantly connected with motorization resulting in increased demand for transport infrastructure.

ii. **Long commutation:** Besides experiencing congestion, people are spending an increasing amount of time to travel between their residence and workplace.

iii. **Public transport inadequacy:** The public transport system in several cities needs to be strengthened and expanded.

iv. **Lack of concern for non-motorized transport:** Lack of facilities for walkers and bikes while planning provision of road infrastructures in urban areas is another concern requiring redressal.

v. **Environmental impacts and energy consumption:** Pollution, as well as noise, generated by traffic circulation is becoming a major impediment to the quality of life and even the health of urban populations. Congestion is also leading to stop and go operation of motorised vehicles and increased consumption of fuel.

vi. **Accidents and safety:** Growing traffic in urban areas is leading to accidents and fatalities.

21.3 Need for ITS Architecture

ITS can be effective in achieving the objectives relating to provide solutions transportation related challenges. ITS architecture could be a useful tool for integrating ITS technique into planning process. ITS architecture can be defined as comprehensive image of functions that have to be performed (user services), physical entities wherever these functions reside (subsystems), interfaces between subsystems (information flows), communications requirements for interfaces and stakeholder roles. The first parts of ITS architecture are subsystems and information flows.

Subsystems: Subsystems are individual items of the general ITS that perform specific functions like managing traffic, providing traveller's information, or responding to emergencies. Subsystems embrace centre systems, wayside equipment, vehicle equipment and traveller devices that participate in ITS.

Information Flows: Information flows outline the information, knowledge and data that is exchanged between subsystems like traffic information, or surveillance and sensor control data. They depict ITS integration by illustrating the information links between subsystems. In ITS, this integration is technical as well as institutional.

As urban areas expand and more roadways are interlinked with each other, operations and maintenance of this technology is imperative. Therefore ITS architecture has emerged as an effective tool to oversee the physical and virtual networks interacting with ITS.

21.3.1 *Logical Architecture*

Fig. 21.1 shows the interaction of 'manage traffic' method with different processes. Every method is broken down into additional sub processes. The sub process is further broken down into next level of sub process that are known as process specifications (P-specs) lowest level. These p-specs are needed to be performed to meet the required user services.

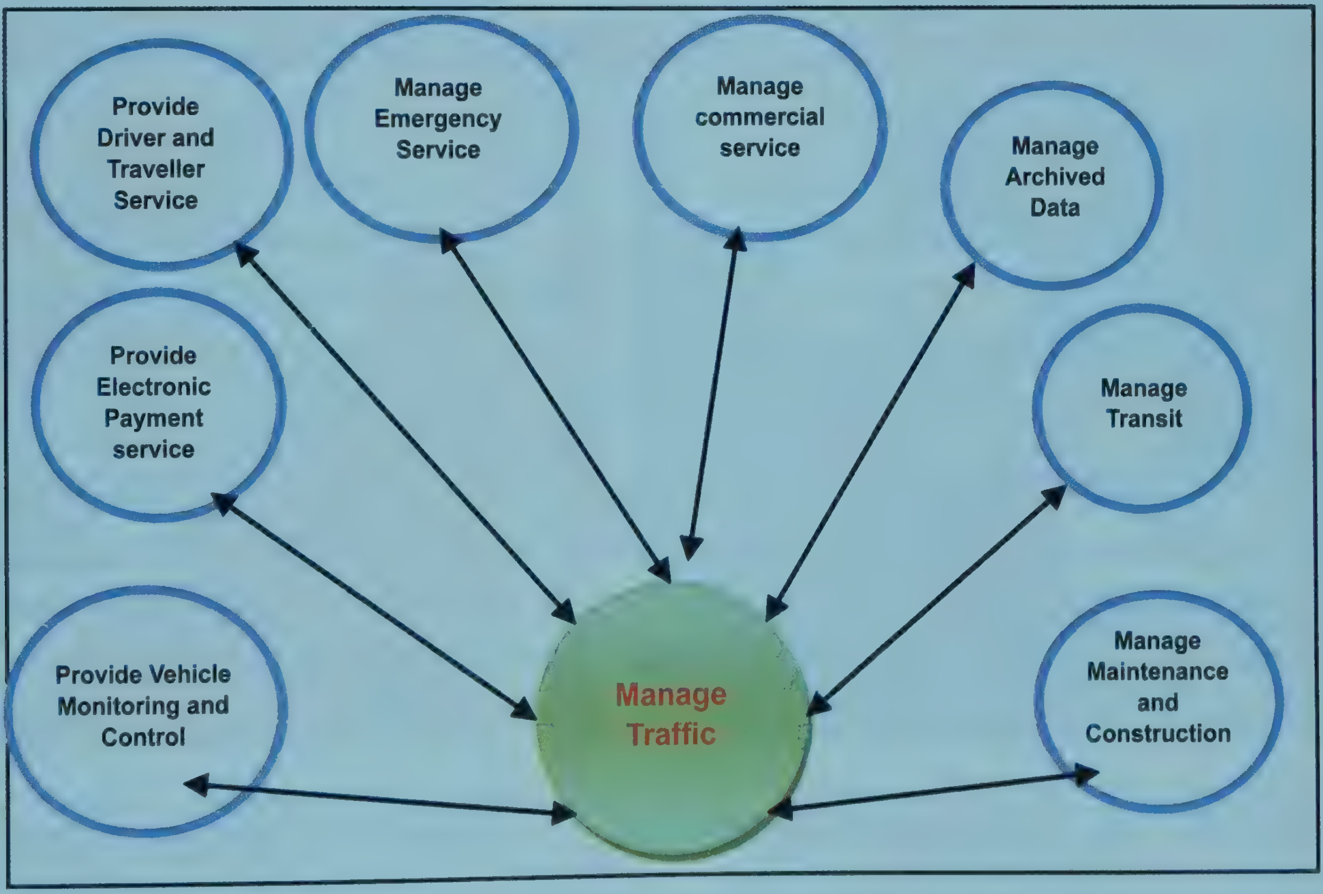

Provide Driver and Traveller Service
Manage Emergency Service
Manage commercial service
Manage Archived Data
Provide Electronic Payment service
Manage Transit
Provide Vehicle Monitoring and Control
Manage Traffic
Manage Maintenance and Construction

Fig. 21.1 Logical Architecture Framework (Source: U.S. Department of Transportation)

21.3.2 *Physical Architecture*

The functions from logical design that serve a similar need are classified into sub systems. With these subsystems, a physical entity is developed to deliver functions. The information flow of logical architecture is combined to define interface between subsystems. The physical architecture of ITS defines the physical subsystems and architectural flows based on the logical architecture. The subsystems are generally classified in four groups as centres, field, vehicle, and travellers. **Fig. 21.2** shows the subsystems and communications that comprise the physical architecture. The system represents aggregation of functions that serve a similar transportation need and closely correspond to physical components of transportation management system. Vehicle cluster consists of five differing kinds of vehicles. The traveller group represents other ways a traveller will access information on the status of the transportation system. There are four differing types of communication systems.

- Fixed point to fixed point
- Wide area wireless
- Vehicle - vehicle communication
- Field - vehicle communication

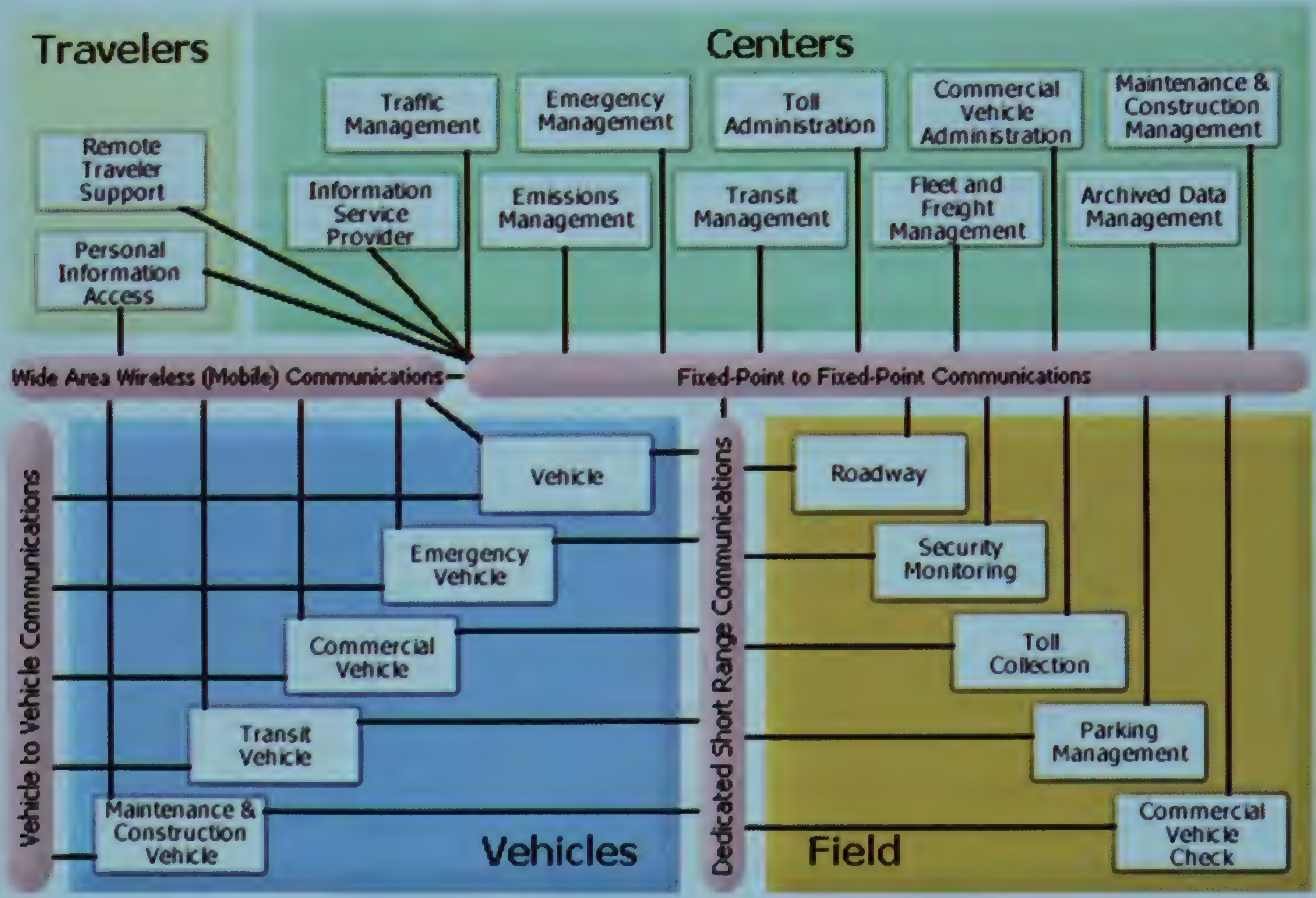

Travelers
Centers
Remote Traveler Support
Personal Information Access
Traffic Management
Emergency Management
Toll Administration
Commercial Vehicle Administration
Maintenance & Construction Management
Information Service Provider
Emissions Management
Transit Management
Fleet and Freight Management
Archived Data Management
Wide Area Wireless (Mobile) Communications
Fixed-Point to Fixed-Point Communications
Vehicle to Vehicle Communications
Dedicated Short Range Communications
Vehicle
Emergency Vehicle
Commercial Vehicle
Transit Vehicle
Maintenance & Construction Vehicle
Vehicles
Roadway
Security Monitoring
Toll Collection
Parking Management
Commercial Vehicle Check
Field

Fig. 21.2 ITS Architecture (Source: U.S. Department of Transportation)

Traffic management system is connected to communications which gets real time information of the transportation system through roadway subsystem that comprise of signal control, detectors, camera, RFID Tags/Readers (Compatible to open Road Tolling), ANPR Cameras and VMS (smart/eVMS) etc. These Smart/Connected/eVMS shall aggregate the data from multiple subsystems and display location specific dynamic real time information.

21.3.3 *Organizational Architecture*

Organizational architecture refers to the engagement of various organizations/stakeholders associated to be a part of the Traffic Management Centre (TMC) or Central Control Centre(CCC) such as NHAI, Traffic Police, Municipal Corporation, PWD, Mobile/WiFi Service providers, Utility service provider companies, etc. for the control and management of traffic movement, incident management, maintenance of street lights, traveller information service, commercial vehicle management, Electronic payment systems, Safety services, Emergency management services, etc. The organizational architecture also defines role of various agencies in a system.

21.4 Detection and Data Collection Methods

21.4.1 *Detection Methods*

Detection methods or sensors are the techniques/components to sense a vehicle or pedestrian moving on the road and then to take necessary action accordingly. Various types of detection systems for vehicles and pedestrians are briefly described in this section.

Automatic Pedestrian Detection Method: In this method, sensors detect the presence of pedestrians and take pre-defined actions for traffic signal control. In this method, the pedestrian does not have to press any button as the system takes care of signal timing automatically. Moreover, if pedestrian takes more time to cross the road (may be due to age or any other reason), the pedestrian green light is adjusted accordingly.

Traffic light as a permanent feature: The traffic lights in this scenario are provided for pedestrian crossings at intersections as a part of traffic signal for vehicular traffic. A specific cycle time is allotted for pedestrian signal. This type of arrangement is recommended where there is continuous flow of pedestrian traffic. The green light for pedestrian crossing is designed on the basis of vehicular flow and pedestrian flow so that both get reasonable time to cross the intersection safely.

Traffic light on request: In this scenario, the traffic lights are provided for pedestrian crossings at intersections as a part of traffic signal for vehicular traffic, but the green light system for pedestrian is not automatic part of vehicular traffic signal system. In this case, at a road side traffic light pole (or special pole is placed), a button is provided. As soon as any pedestrian arrives, he can press the button (pedestrian crossing button), called Pelican Crossing. After a small period of time, the pedestrian gets a green signal to cross the road. These signal timings are adjusted in a way that the drivers get sufficient time to stop his vehicle. This facility is provided where the pedestrian flow is irregular. This type of system is installed at mid blocks based on demand.

Red Light Violation Detection System: Motorists driving through an intersection after the traffic signal has turned red are a safety hazard. When a motorist enters an intersection after the signal light has turned red, it constitutes a Red Light Violation. Heavy manpower and resources are required to enable police departments to enforce violations for a long period of time. Automation of traffic Violation Detection would help in improved management and enhanced compliance.

ANPR (Automatic Number Plate Recognition) cameras having a combination of IR (Infra Red Camera) and Visual Spectrum Camera are used as part of an automated Red Light enforcement program. This will enable system to perform Automatic Vehicle Identification (AVI) with the help of a central processing unit, and a storage subsystem to record information such as date, time and location. This provides enough documentary evidence for violation and would also instill a sense of discipline in road users for obeying traffic signals.

21.4.2 *Data Collection Methods*

Sensing Technologies: Sensing systems for Intelligent Transportation System are vehicle and infrastructure based networked systems, e.g., intelligent vehicle technologies. Pavement loops are used to sense the presence of vehicle demand at intersections and parking lot entrances.Pressure pads are used to sense the presence of pedestrians waiting to cross a roadway.

Radar and acoustic sensors are also used for detecting vehicles on the roadway. It works along with transmission of radar pulses. A portion of the energy is reflected or scattered from the vehicle and roadway back toward the sensor and this energy is received and interpreted. The major benefits are low power, more accurate technology for detecting speed, traffic count accuracy and easy installation.

Automated Number Plate Recognition (ANPR): The use of ANPR technology has grown rapidly, seeing rapid and widespread adoption worldwide as a means to providing more accurate and timely information in making critical business and enforcement decisions. The advancements include numerous capture technologies with an integrated dual lens camera and ANPR processor in one compact housing. It is seen as critical that the camera processor have in-house OCR algorithm mechanism. Plate detection and plate character recognition happen inside camera hardware thereby ensuring low bandwidth usage as well as speed of transmission and therefore preventive/corrective action is possible.

Inductive Loop Detection: One or more loops of wire are embedded under the road and connected to a control box. It is an established technology and not impacted by environmental conditions. Accurate in detecting vehicle presence and also performs well in both high and low volume traffic.

Video Vehicle Detection: Video Vehicle Detection (VVD) is one of the most widely used methods. Video detection is an image processor. It consists of a microprocessor-based CPU and software that analyzes video images. Using a mouse and interactive graphics, the user places virtual "detectors" on the video image displayed on a monitor information/data can be progressively transmitted to a server for real-time analysis.

Bluetooth Detection: Bluetooth is an accurate and inexpensive way to measure the travel time and undertake analysis of origin and destination pattern of trips. Bluetooth is a wireless standard used for communication between electronic devices such as mobile phones, smart phones, headsets, navigation systems, computers, etc. Bluetooth road sensors are able to detect Bluetooth MAC addresses of Bluetooth devices in vehicles passing. These sensors are able to calculate the travel time and provide data for origin and destination matrices if they are interconnected.Compared to other traffic measurement technologies, Bluetooth measurement has some differences.

- Accurate measurement points with absolute confirmation to provide to the second travel times.
- Is non-intrusive, which can lead to lower-cost installations for both permanent and temporary sites.
- Is limited to how many Bluetooth devices are broadcasting in a vehicle so counting and other applications are limited.
- Systems are generally quick to set up with little to no calibration needed.

Radio-Frequency Identification (RFID): Radio-Frequency Identification (RFID) is the wireless use of electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects. The tags contain electronically stored information. It is widely used in industries and transportation and communication purposes. For example, RFID placed in the road infrastructure can identify and communicate with the vehicles plying on the road through the following RFID system. **Fig. 21.3** shows the operation of RFID.

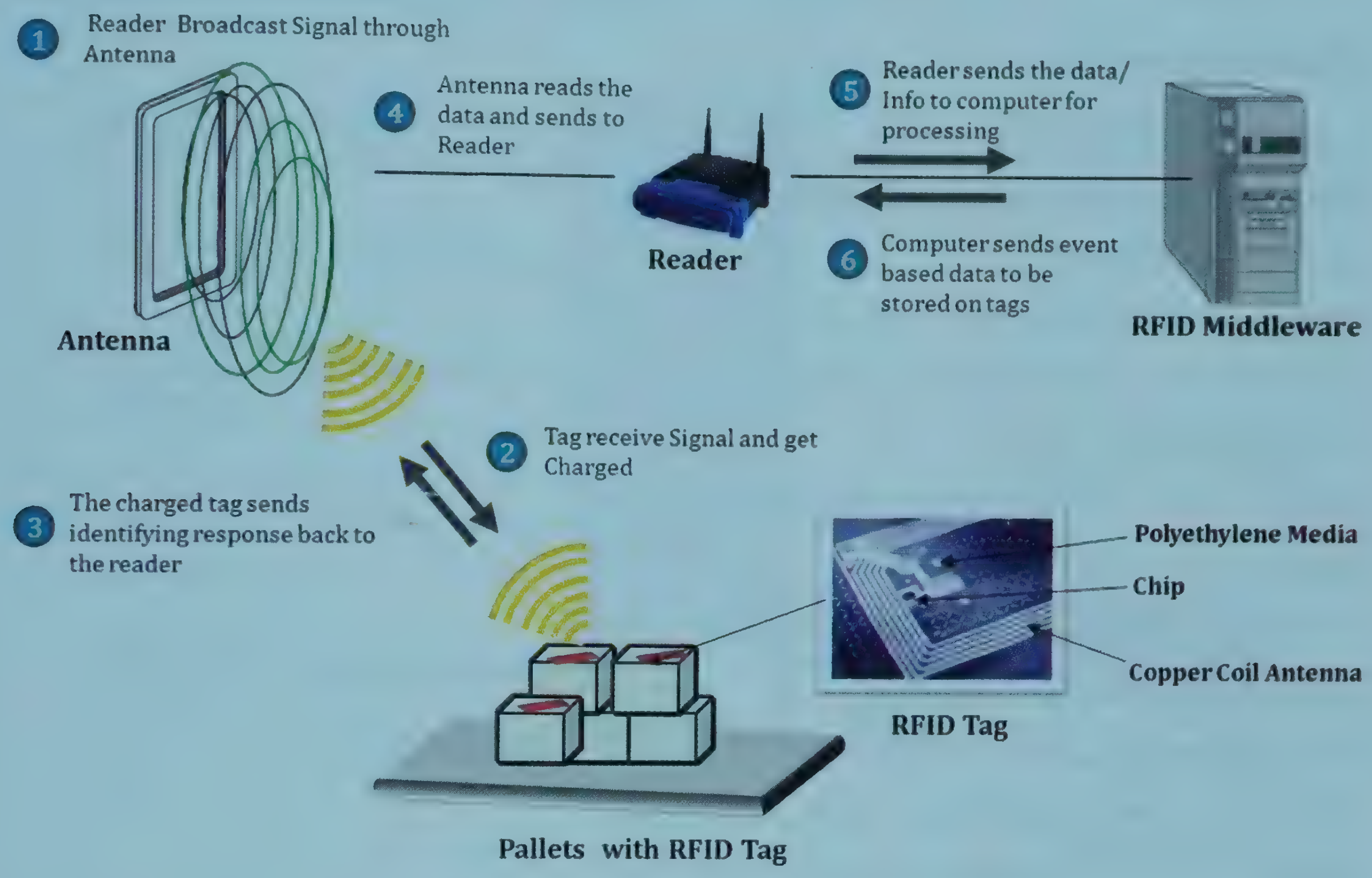

① Reader Broadcast Signal through Antenna
④ Antenna reads the data and sends to Reader
⑤ Reader sends the data/ Info to computer for processing
Reader
⑥ Computer sends event based data to be stored on tags
RFID Middleware
Antenna
② Tag receive Signal and get Charged
③ The charged tag sends identifying response back to the reader
Polyethylene Media
Chip
Copper Coil Antenna
RFID Tag
Pallets with RFID Tag

Fig. 21.3 Operation of RFID

Infrared: It is a wireless used in wireless technology devices or systems that transfer data through infrared (IR) radiation. Infrared is electromagnetic energy at a wavelength which is somewhat longer than those of red light. The operation is more or less similar to RFID. It works with passive working mechanism with electric sensor that measures IR light radiating from all objects with temperature above absolute zero. It means that a Passive Infra Red (PIR) device does not generate or radiate any energy for detection purposes. In this case, IR light is being generated from vehicles plying on the road. It can classify vehicles, speed and density of vehicles. It is easy to install with probability of detection along with good resistance to rain, fog, dust and snow.

Microwave Sensors: It is also known as Dopplers sensors or Radar or RF that help detect walking, running, human targets etc. It produces electromagnetic wave (RF) field between transmitter and receiver that help to create an invisible volumetric detection zone, if anybody enters into that zone, change in field is recognized giving rise to sound of alarm. This sensor can also be effectively used for recording traffic data.

21.5 ITS for Urban Traffic Management

The major objectives of Traffic Management System (TMS) are optimizing capacity, minimize journey time and ensuring safety. In implementing any traffic management solution, the authorities face challenges to address concerns related to safety, efficiency and capacity. Advance Traffic Management in urban area appears to be one of the best options in this regard.

21.5.1 *Advanced Traffic Management System (ATMS)*

The Advanced Traffic Management System (ATMS) field is a primary subfield within the Intelligent Transportation System (ITS) domain. The ATMS also helps in managing the traffic demand on various corridors. ATMS is of great help in optimising the budget meant for providing solutions to the traffic congestion. It also helps in maintaining the various transport related infrastructure for better services. **Fig. 21.4** shows the functioning of ATMS.

ATMS Functional Areas are:

- Real-time traffic monitoring
- Dynamic message sign monitoring and control
- Incident monitoring
- Traffic camera monitoring and control
- Active Traffic Management (ATM)
- Chain control
- Ramp meter monitoring and control
- Arterial management
- Traffic signal monitoring and control
- Automated warning systems
- Road Weather Information System (RWIS) monitoring
- Highway advisory radio
- Urban Traffic Management and Control

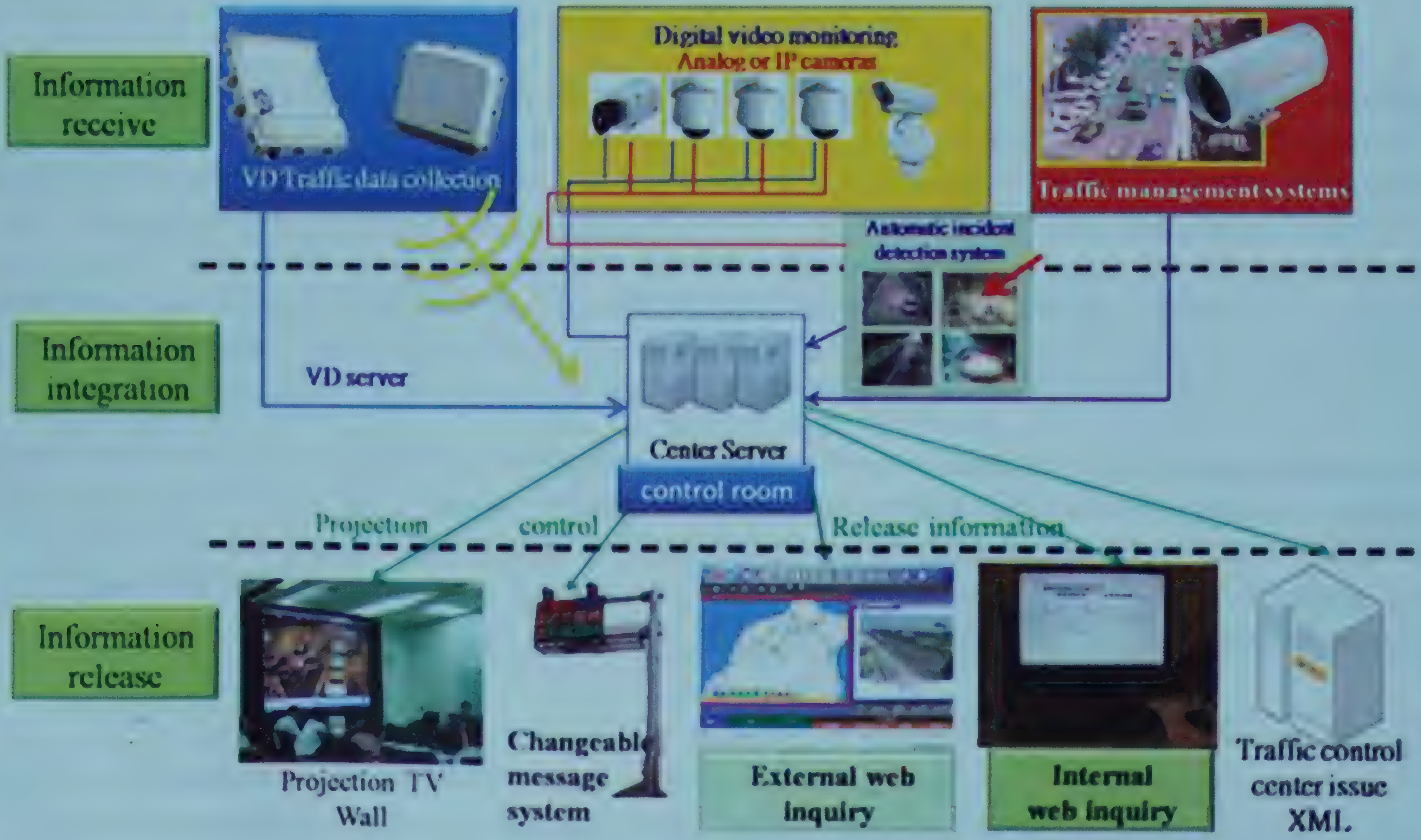

Information receive
VD Traffic data collection
Digital video monitoring
Analog or IP cameras
Traffic management systems
Automatic incident detection system
Information integration
VD server
Center Server
control room
Projection
control
Release information
Information release
Projection TV Wall
Changeable message system
External web inquiry
Internal web inquiry
Traffic control center issue XML

Fig. 21.4 ATMS Data Collection System

21.5.2 *Traffic Management Centre (TMC)*

When it is not possible to set up a comprehensive Traffic Management Control Centre (See **Fig. 21.5**) due to paucity of funds, traffic management measures for a single location or for a set of locations are commonly provided such as ANPR, Red Light Camera, Speed/Detection/ Enforcement Camera, VMS in urban areas. The following are some demonstrations as a part of ITS driven applications for Traffic Management.

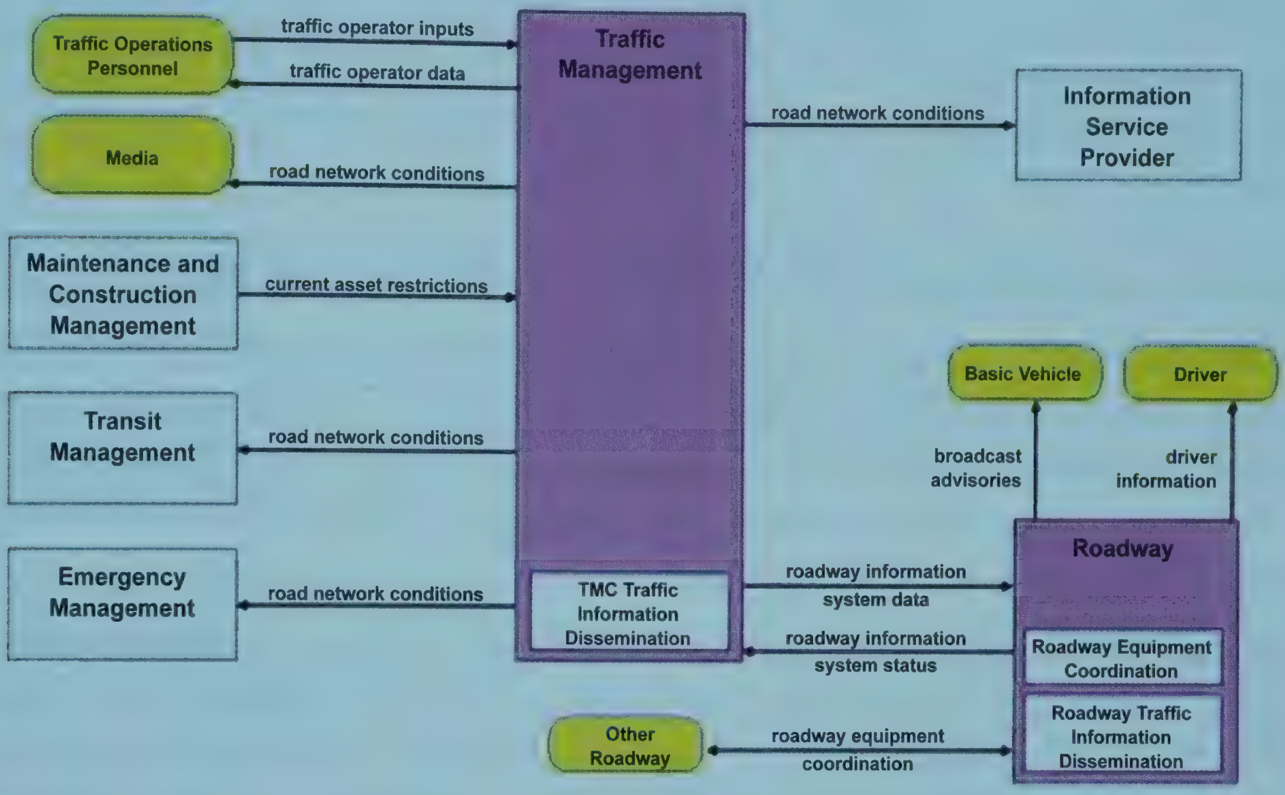

Traffic Operations Personnel
traffic operator inputs
traffic operator data
Traffic Management
Media
road network conditions
road network conditions
Information Service Provider
Maintenance and Construction Management
current asset restrictions
Basic Vehicle
Driver
Transit Management
road network conditions
broadcast advisories
driver information
Roadway
Emergency Management
road network conditions
TMC Traffic Information Dissemination
roadway information system data
roadway information system status
Roadway Equipment Coordination
Roadway Traffic Information Dissemination
Other Roadway
roadway equipment coordination

Fig. 21.5 Concept of Traffic Management Control Centre

Arterial Management: Arterial management systems manage traffic along arterial roads, employing traffic detectors, traffic signals, and various means of communicating information to travellers. These systems make use of information collected by traffic surveillance devices to smooth the flow of traffic along travel corridors. Motorists are now able to receive relevant information on location specific traffic conditions in a number of ways, including dynamic message signs, highway advisory radio, in-vehicle signing, or specialized information transmitted only to a specific set of vehicles.

Transit Management: Transit ITS services include surveillance and communications, such as Automated Vehicle Location (AVL) systems, Computer-Aided Dispatch (CAD) systems, and remote vehicle and facility surveillance cameras, which enable transit agencies to improve the operational efficiency, safety, and security of the nation's public transportation systems.

Traffic Incident and Emergency Management: These systems can reduce the effects of incident-related congestion by decreasing the time to detect incidents, the time for responding vehicles to arrive, the deployment of emergency medical services, and large and small-scale emergency response and evacuation operations and the time required for traffic to return to normal conditions.

Electronic Payment for Congestion and Road Pricing: These systems employ various communication and electronic technologies to facilitate commerce between travellers and transportation agencies, typically for the purpose of paying tolls and transit fares.

Traveller Information: Traveller information derived from real life data transmission from the traffic management centre to help road users to take appropriate travel decision, use a variety of technologies, including Internet websites, telephone hotlines, as well as television and radio, to enable users to make more informed decisions regarding trip departures, routes, and mode of travel.

Information Management: ITS information management supports the archiving and retrieval of data generated by other ITS applications and enables ITS applications that use archived information. Decision support systems, predictive information, and performance monitoring are some ITS applications enabled by ITS information management. In addition, ITS information management systems can assist in transportation planning, research, and safety management activities.

Crash Prevention and Safety and efficiency of commercial operations

Crash prevention and safety systems detect unsafe conditions and provide warnings to travellers to take action to avoid crashes. These systems provide alerts for traffic approaching at dangerous curves, off ramps, restricted overpasses, highway-rail crossings, high-volume intersections, and also provide warnings about the presence of pedestrians, and bicyclists, and even animals on the roadway.

Collision Avoidance Systems: To improve the ability of drivers to avoid accidents, vehicle-mounted Collision Warning Systems (CWS) continue to be tested and deployed. These applications use a variety of sensors to monitor the vehicle's surroundings and alert the driver of conditions that could lead to a collision. Examples include forward collision warning, obstacle detection systems, and road departure warning systems.

Emergency Vehicle Management (EVM)

The EVM will provide for more efficient management and assignment of emergency response vehicles. Its intent is to reduce the amount of time between a public safety operator's notification of an incident and the arrival of emergency personnel on the accident location. This service will provide public safety agencies with fleet-management capabilities, route guidance, and signal priority and pre-arrangement for emergency vehicles. The primary users of EVM are police, fire, and hospitals.

21.6 Phase for Implementation of ITS

Various transportation challenges being faced in metropolitan cities cannot be addressed using ITS tools alone. They need to be combined with other engineering interventions for a successful traffic and transport management system plan.

The traffic management measures need to be implemented in a phased manner so that the experience from the earlier phases can be utilized in the later phases. Thus based on available expertise and severity of the ground reality, the following suggested phases or components of ITS can be adapted to suit the prevailing conditions in a city. Depending on actual needs, one can add or delete systems or subsystems described here. For details, refer IRC:SP:110 "Application of Intelligent Transport System For Urban Roads".

CHAPTER 22

KNOWLEDGE DEVELOPMENT

22.1 Government Initiatives

Urban economic activities are dependent on infrastructure, mainly roads and transport infrastructure facilities. The existing network of urban roads, currently around 3 lakh km, is under stress due to ever increasing traffic. There is need for augmentation of capacity and quality of service of urban roads, and this would require better design and state-of-art technology. The need for national research and development in all branches of science and technology was clearly recognized by the planners as early as the 1950's. The establishment of a chain of National Laboratories under the Council of Scientific and Industrial Research (CSIR) was a major step in this direction. The Central Road Research Institute (CRRI) was established as a part of this set-up. Some road research Institutes were also established at the state level, notable among them being, Highway Research Station (HRS), Chennai; Maharashtra Engineering Research Institute, Nashik, Gujarat Engineering Research Institute, Vadodara; Assam Road Research and Training Institute, Guwahati; Uttar Pradesh Road Research Laboratory, Lucknow; Bihar Road Testing and Research Centre, Patna.

Government of India has emphasized on the need for improving mobility and accessibility: it envisaged development of the total road network in the country. This included phased removal of deficiencies in the existing road network, widening and strengthening of pavement, rehabilitation and reconstruction of weak and dilapidated bridges, maintenance and road safety measures. With growing road network of the country and with ambitious road development plans, the role of Research and Development (R&D) inputs becomes all the more important. Side by side, attention needs to be focused on conducting research and evolving technology initiatives relevant for urban transport including roads and streets with the support of research and academic institutions at the national and state level. This pace needs to be accelerated. Environmentally optimized designs achieving resource efficiencies and enhanced durability from investments should be the key objectives.

The Highway Research Board (HRB) was constituted in the year 1973 under the aegis of Indian Roads Congress (IRC) as the Forward Looking Group of the Science & Technology Advisory Committee (STAC) of the Ministry of Road Transport & Highways. The Director General (Road Development) & Special Secretary to the Govt. of India, Ministry of Road Transport & Highways is the ex-officio Chairman of HRB. The Secretary General, IRC is the Secretary of this board; and experts in road sector from the Research Institutions, Government Departments, Universities, Engineering Colleges and the Business Sector are the members of HRB. IRC-HRB with the help of Identification Monitoring & Research Application Committee (IMRA) and Core Group and Technical Committees of IRC identify the priority areas and action plan in road sector and thereafter forward recommendations to the MoRTH.

A major thrust to the research in the highway sector was given by the Ministry of Road Transport and Highways in early 1980s. About a hundred research projects related to various aspects of roads, bridges, traffic management and safety have been taken up so far. These research schemes have provided useful knowledge for cost-effective solutions to the problems faced on the ground, and have helped in development of several design guidelines and standards suited to Indian conditions.

Now, systematic visionary research need to match the huge road development programmes being undertaken in the country since the year 2000. There is need to reap the benefits of new materials, innovative technology and processes. The current gap in road research should be addressed on priority. The research and knowledge development is important for faster development, so that the innovations will result in cost effective solutions which will provide better performing and safer highways in the country. As technologies are changing at a fast pace, we must come up with new ideas, learn from our experiences and develop capacity to compete and innovate user friendly technologies.

The various components of R&D strategy should be improvement in design, modernization of construction techniques, introduction of improved materials conforming to latest standards, evolving better and appropriate specifications, encouraging development and use of new technologies, use of marginal materials, climate resilient designs and promotion of green technologies, etc.

For urban roads and streets, Ministry of Housing and Urban Affairs (MOHUA) is the administrative ministry. Investments in urban transport infrastructure have been witnessing a quantum jump during the current century:

- Period 2002-07 : Rs. 1,27,107 crore
- Period 2007-12 : Rs. 2,78,658 crore
- Period 2012-17 : Rs. 3,88,308 crore (Allocation by NITI Aayog)

The main thrust of research and knowledge development in the urban roads sector should be to build a sustainable, environment friendly and climate resilient road infrastructure. The existing technology policy needs to be reformulated in the light of the scenarios emerging from technological developments taking place throughout the world, namely, increased traffic, depleting sources of construction materials, environmental damage and aesthetic considerations. There is need to be more aggressive in acquiring and applying advanced technologies in wide range of fields, including roads, bridges, tunnels, traffic-transportation and incident management. Investment in road research should be viewed as a long term investment, to put the country on higher pedestal in the field of urban roads and streets.

22.2 Emerging R&D Areas

Some of the more important thrust areas for Medium Term R&D work and Long Term R&D requiring immediate attention are provided in the link (http://www.serb.gov.in/pdfs/brainstorming-sessions/DST_Workshop_Final_Report.pdf). These thrust areas were identified through a National Workshop of research conducted at IIT Kanpur by Department of Science and Technology in the year 2015. See **Box 21.1** for major thrust areas relevant to urban roads.

22.3 Budgetary Allocations

In view of the vital importance of R&D in the areas of planning, design, construction, maintenance and rehabilitation of urban roads, an appropriate percentage of the amount of investment in urban roads may be set apart for R&D work. As has been the experience in the developed countries, R&D efforts do pay handsome dividends in the long-run by way of more cost-effective, performance-based designs and improved performance of roads, with prolonged life and reduced

Box 22.1 Major thrust areas of research relevant to Urban Roads

- Understanding pedestrian crossing behaviour for developing warrants for different types of crossing facilities
- Understanding bicycle traffic pattern and characteristics
- Understanding travel pattern of NMV (Non-motorized Vehicle) users
- Understanding paratransit modes and their users
- Studying innovative travel behaviour data collection techniques and their reliability and accuracy
- Understanding traveller responses to various means of multi-modal integration
- Developing Inter-city passenger travel demand models
- Understanding the impact of information and communication technologies (ICT) on travel behaviour and transport efficiency
- Developing freight demand models
- Understanding the dynamics of land-use and transportation
- Developing transit routing algorithm.

maintenance costs. Municipal agencies need to allocate a portion of their annual budget for research. MOHUA may consider creating a dedicated budget head for Research Development and Technology (RD&T) initiatives for urban transport and a suitable allocation out of that may be utilized for the Urban Roads Sub-Sector.

22.4 Institutional Arrangements

Ministry of Housing and Urban Affairs (MOHUA) is ideally positioned to be the apex body to fund and get the R&D schemes related to urban roads implemented. They can also monitor the progress of the research projects. Since the Highway Research Board (HRB) of the IRC is like a Forward Looking Group for the R&D in the road sector as a whole, a close liaison is needed between the MOHUA and the HRB.

Core group for knowledge development on urban roads may be established within the HRB of IRC with support from MOHUA for facilitating development of database, further research, dissemination of knowledge and information on various aspects of urban roads (planning, engineering, construction, maintenance etc.).

The CRRI and the state level road research and academic institutions will have to carry the major burden of the R&D work. With the increased focus on urban roads, the CRRI would need to augment its area of work for urban roads in close association with the MOHUA. Academic institutions such as IITs/NITs, which have already been involved in various aspects of Urban Roads should join hands in this endeavour. They have already been playing a useful role in promoting research in the highway sector.

22.4.1 *Institute of Urban Transport, India (IUT)*

The Institute of Urban Transport India (IUT) was established in May, 1997 as a professional body under the aegis of the MOHUA. It is a premier professional non-profit making organization and registered under the Societies Registration Act. The objective of the Institute is to promote, encourage and coordinate the state of the art of urban transport including planning, development, operation, education, research and management. IUT is required to manage country wide research. Accordingly, IUT has been proposing a countrywide agenda for research in the country to the MOHUA for appropriate action. In addition, IUT undertakes research activities as a part of its routine activities. Some of the research studies conducted by IUT are:

Life Cycle Cost (LCC) of five MRT modes namely Metro Rail, Mono Rail, Light Rail (separately for at grade and elevated), Bus Rapid Transit and City Bus Services.

22.4.2 *Centers of Excellence*

For urban transport, the MOHUA has also identified a few academic institutions as Centers of Excellence in various disciplines of urban transport. The Center of Excellence in Urban Transport, CEPT University (CEPT-CoE), established in 2009 is one such initiative. It has been envisaged as a resource center for dealing with issues in urban transport planning and management. The Center is also involved in several research works like documentation of design evolution of Janmarg BRTS in form of a book, developing a manual on design of footpaths in urban areas and a guideline document on planning and design of bus stations, research on land use transport integration and road safety levels in Ahmedabad etc. Centers of Excellence are also operating at IIT Roorkee (CTRANS), IIT Delhi (TRIPP), IIT Madras (CoE by MOHUA), NIT Warangal to promote multidisciplinary research with presence of different academic departments. They have access to diverse expertise to address many challenging problems.

22.5 Research Funding Schemes

There are different schemes of the Government of India which are aimed at promoting R&D and they can be used for supporting research activities in Urban Roads Sector. Recently IMPRINT and UAY schemes have been started with scope for participation from user Ministry and Industry. DST funds through Science and Engineering Research Board (SERB) to IITs/NITs research projects. These projects can cover Urban Roads.

22.5.1 *IMPRINT*

There is an exigent need to make the education institution's research to be focused on the needs of society. With this objective, the Government of India has launched several schemes and one of the important schemes is the IMPRINT (Impacting Research Innovation and Technology). IMPRINT provides a comprehensive vision that guides research into areas that are predominantly socially pertinent, relevant to address engineering problems and challenges facing India by converting existing knowledge into viable technology.

IMPRINT is a novel initiative supported by the Ministry of Human Resource Department (MHRD). It is a collaboration between various Indian Institutes of Technology (IITs) and Indian Institute of Science (IISc) Bangalore to enable, empower and embolden the nation for inclusive growth and self-reliance. It is an opportunity before the engineering fraternity of the country to integrate with the society by creating conducive environment for spreading innovative thinking in educational institutions and providing viable engineering solutions. Consideration could be given to cover research on urban roads as part of this initiative.

22.5.2 *Uchchatar Avishkar Yojana (UAY): Industry-Academia Coordination*

Uchchatar Avishkar Yojana (UAY) has been initiated by the Govt. of India with a view to promote innovation of a higher order that could directly impact the needs of industry/industries and can improve the coordinated action between academia and industry. The guidelines were decided in the IIT Council meeting in October, 2015. The UAY scheme is aimed to promote innovation in areas that have direct relevance to the manufacturing and design industry and to have outcome oriented research funding. Initially, the project proposals under UAY are accepted from the IITs and IISc (Bangalore) with a possibility of collaboration with industries within or outside India. This window may also be available for research in urban roads.

22.5.3 *DST*

Department of Science and Technology (DST) was established in May 1971, with the objective of promoting new areas of science and technology and to play a pivotal role in promotion of science and technology in the country. The department has wide ranging activities from promoting high and basic research and development of cutting edge technologies on one hand to service the technological requirements of the common man through the development of appropriate skills and technologies on the other.

22.5.4 *SERB*

Science and Engineering Research Board (SERB) is an autonomous body under the Department of Science and Technology, Government of India, established by an Act of the Parliament of India in 2009. The Board is chaired by the Secretary to the Government of India in the Department of Science and Technology and has other senior government officials and eminent scientists as members. Supporting basic research in emerging areas of Science and Engineering are the primary and distinctive mandate of the Board.

22.5.5 *TIFAC*

Technology Information, Forecasting and Assessment Council (TIFAC) is an autonomous organization set up in 1988 under the Department of Science & Technology to look ahead in technologies, assess the technology trajectories, and support technology innovation by network actions in select technology areas of national importance.

In 1993, TIFAC embarked upon the major task of formulating a Technology Vision for the country in various emerging technology areas. The outcome of the Technology Vision 2020 exercise led to the development of 17 documents, including sixteen technology areas and one on services. The effort was a unique and pioneering exercise that involved more than 5,000 experts including scientists, technologists and corporate managers from academia, industry and the government.

TIFAC continues to strive for technology development of the country by leveraging technology innovation through sustained and concerted programmes in close association with academia and industry. Technology also plays a key role in resource efficiency strategies and easing the pressure on available resources. Accordingly, TIFAC undertook another visionary exercise and formulated Technology Vision 2035. In order to get comprehensive insights, Advisory Committees comprising of expert groups have been formed to cover twelve thematic areas such as education, energy, environment, food and agriculture, habitat, information and communication, infrastructure, materials and manufacture, medical science and health care, transportation and water technologies.

22.6 Dissemination

The municipal corporations may consider holding of regular workshop for dissemination of various codes, manuals, guidelines on urban transport including urban roads and streets.

CHAPTER 23

CAPACITY BUILDING AND SKILL DEVELOPMENT

23.1 Context

Investments of around Rs.50,000 crore to Rs.60,000 crore per year on roads in urban areas are envisaged. This represents a high level of investments in roads in urban areas (compared to annual investments in PMGSY and other rural roads of Rs.30,000 crore which is delivered well, thanks to continuous effort in standardization of designs, procurement documents and capacity building of all stakeholders). To ensure value for money from the investments in urban roads, there is need to ensure quality and due diligence in planning, design, construction, operation and maintenance management of road infrastructure by the urban local bodies and other road agencies entrusted with the road network in urban areas. This will require improvement of skills, knowledge and capacity of decision makers, engineering personnel, staff members of consultancy organisations and workers of contractors, etc. Even the city councillors need to have some understanding of issues involved in planning and design of road space and infrastructure from the angle of mobility and accessibility planning for cities with emphasis on safe and comfortable movement of people and goods on the road network. This would help in getting their support for continued stress on proper traffic and transportation studies and technology development in achieving economies in provision and management of road infrastructure in urban areas and human aspects of road design as an inclusive, safe and equitable public good. The city corporation/council will have a key role to play in ensuring this. This chapter draws heavily from the IRC document on capacity building and skill development of road agencies in urban areas IRC:SP:111 "Capacity Building of Road Agencies in Charge of Implementation of Road Projects in Urban Areas".

Apart from public sector, funds for road development would need to be tapped from private sector sources-equity from entrepreneurs and debt from banks and other financing institutions. This throws up demand for not only skills and competence in technical designs, social and environment safeguards, procurement processes, project management and maintenance, contract administration but also for financial and legal skills to ensure fair allocation of risks and rewards in implementation of PPP projects. Equally important is to ensure community participation and consensus building with participation from all kinds of future road users, and not just the motorists.

23.2 Key Requirement

The Skills, Knowledge and Attitude (SKA) of various functionaries in the urban local bodies and road agencies responsible for urban roads have to be enhanced by way of improving their overall technical knowledge (road engineering, safe and inclusive designing, traffic engineering and transport planning for all road user groups including public transport users, non-motorized transport users and paratransit users) and managerial ability for efficient delivery of road infrastructure projects and subsequent operations and management. In urban areas, they also have to regularly interact with other departments such as traffic police, utilities, transport corporations, metro rail authorities. It is essential that these functionaries:

- are acquainted with fundamentals of inclusive transport planning and traffic engineering
- are acquainted with best national/international practices;
- acquire both theoretical and practical knowledge in core areas of planning, design, social and environment safeguards, safety planning and engineering measures, construction and maintenance of road projects;
- can effectively associate with and oversee the tasks entrusted to consultants;
- can manage efficient and effective delivery of projects by the contractors;
- are sensitive to the concerns and needs of all types of road users and local communities served by the road;
- are aware of, and can enforce, universal access standards in the planning, design, implementation, construction, operation and monitoring of transport infrastructure;
- keep up the momentum towards enhanced governance (better accountability, efficiency and transparency) and redressal of grievances raised by contractors and the community.
- undertake post-implementation audits for accessibility and continued safety requirements.

Side by side of skill development of road agencies, attention is to be focused equally on skill development of consultants and contractors and their project managers, construction workers and equipment operators.

The technicians, foremen and supervisors form the backbone of the road construction sector for implementation on the ground. However, absence of an apprentice culture in the entire construction sector and the highly unorganised nature of the industry have inhibited the institutionalisation of the role of these supervisory cadre staff, and have affected the productivity of construction workers and equipment operators. This weak link requires special attention for successful execution of works designed by the engineering professionals.

23.3 Main Areas of Focus

The topics for the capacity building module for road development could essentially be:

- Visioning and planning for road space
- Creating safe and inclusive designs for safeguarding pedestrians and cyclists and other vulnerable user groups
- Conducting road safety, accessibility audits and scientific crash investigations
- Setting up institutional mechanisms to ensure integrated planning and coordination with other infrastructure and service providers like water, sewage, electricity, traffic police and telecom departments.
- Rethinking road space allocation and use by creating dedicated infrastructure for public transport, non-motorised transport and para-transit
- Community engagement

These topics could be further refined and customised to meet the needs and relevance of the agencies/individuals being trained.

23.4 Core Competence

Except for a few states, there is lack of core competence in road departments. Road Departments in the urban local bodies should have a strong Design Directorate with minimum of five wings with capacity for in-house design and monitoring of outputs of the task outsourced to private consultants and individual experts:

a) Traffic Engineering and Transport Planning
b) Pavement Engineering Design
c) Bridge Structures Design
d) Social and Environment Safeguards
e) Accessibility and Safety Standards

The Design Directorate should have at least 4 to 5 professionals at various levels with specialized qualifications in relevant discipline. Those who do not possess minimum of M.Tech qualifications should be provided with long-term courses in relevant discipline with support of national/ international academic institutions. These engineers should be considered as recognized professionals in their niche area. Proper infrastructure – hardwares, softwares, office equipments, etc. and office space would of course need to be planned and provided.

Apart from in-house design, the various specialists of the Design Directorate should also be utilised for proof checking and overseeing the work of design consultants. Needless to add that currently, this is an area of some concern and is a contributory factor in change of work scope during execution and avoidable disputes and even genuine claims raised by the contractors. Designs have to be optimal to suit the condition of soil and anticipated traffic so that both over design and under design are avoided and value for money invested is achieved. There is also need to improve the system of topographic, soil, material, geotechnical and hydraulic surveys and investigations besides designs and preparation of bid documents.

There needs to be a strong emphasis on the continuous involvement of all relevant stakeholder-groups (all persons including those with reduced mobility and disabilities, city-consultants, local/ regional authorities, etc.) from the very start of the project. Towards this goal, a two-pronged approach is required.

Establish a system of effective stakeholder involvement and communication: Create platforms for educating, sharing ideas and information and learning from each-other's experiences with the stakeholders, in all the phases of creating and maintaining inclusive transport systems. The stakeholders will include users, planners, architects, engineers, contractors, civic agencies, and Government departments that construct and maintain public facilities and outdoor environment.

Capacity building of those engaged in the planning, implementation, operation and maintenance of public infrastructure. Raise awareness among the local and regional decision-makers of the link between accessibility and energy-efficiency in transport, by initiating communication among all relevant local and regional stakeholders to improve accessibility.

Establish a structure of systematic and effective approach for comprehensive design including universal accessibility in planning, implementation, and evaluation: Piecemeal implementation will not be effective till the intermediate links are not established. For example, the efficacy of an accessible BRT or Metro system will be incomplete if people cannot access the footpaths, roads and intermediate pedestrian infrastructure to reach these facilities. A seamless trip chain therefore is necessary to close the loop.

23.5 Unified Metropolitan Transport Authority (UMTA)

The Unified Metropolitan Transport Authority (UMTA) will ensure that the various transport agencies talk to each other. This will make sure proper planning, design, construction and maintenance of roads in an effective manner. This is an umbrella body that will bring various mobility services under it with an eye on resolving issues like first- and last-mile connectivity. Bangaluru state government proposed the concept of UMTA to unify citys transport utilities. In India other Cities like Vijayawada, Bhopal, Hyderabad, Jaipur, Kochi, Lucknow and Trichy already have their versions of UMTA law.

23.6 Skill Development and Training Strategy

23.6.1 *Target Groups*

The target groups for training and skill development should be municipal bodies and road agencies responsible for urban roads, consultants normally engaged for DPRs for roads, bridges, flyovers and for supervision of construction works, contractors engaged in construction and maintenance of urban roads.

23.6.2 *Training Strategy*

The training strategy should cover the following aspects:

i) **All stakeholders:** Urban Local Bodies and road agencies for all urban roads within their jurisdiction, contractors, consultants.

ii) **Institutional framework:** Strengthening and networking of existing training and academic institutions, collaboration with international agencies.

iii) **Project cycle:** Traffic and Transportation Studies, planning, design, DPR preparation, procurement, construction, operation and maintenance, evaluation.

iv) **Type of training:** Induction training at entry, training for in-service engineers, refresher courses, short-term and long-term specialized courses. Also, crash training on innovations – like new technologies, access standards, new R&D activities and new international practices where these are required to be introduced to provide value for money.

v) **Level of officers:** At all levels (junior, middle, senior and top management cadre). Fair share for all, special attention for supervisory cadre. Training modules to be specially designed for each level.

vi) **Different aspects:** Transportation studies, traffic assessment, project preparation, alignment selection, scope of work, cost-benefit and financial appraisal (particularly for toll-based projects), procurement procedures, construction management, specifications and quality assurance, legal, land management, contract administration, dispute resolution, negotiation skills, social and environment aspects, GIS, GPS, IT-enabled services, ITS technologies, safety, financial management, asset management, personality development, communication skills, team work. In general identifying the gaps in SKA of the target audience and designing the training curriculum in context to the attendees' needs is a good strategy. The trainer should be flexible and adaptable to focus subjects relevant to the trainees.

vii) **System of incentives:** For department officers, promotion could be linked to participation in skill development and training programmes. Minimum participation in predefined training modules should be crossed before promotion to AE, EE and SE levels. Additionally, a system of monitoring for results by connecting trainees to a mentor and checking with their supervisors would make the promotion process more robust.

viii) **Financing strategies:** Government budget and private sector for contractors and consultants.

ix) **User Interface and Sensitization:** Many commuters face both attitudinal and physical problems while using public transport. It should be mandatory to provide regular and refresher trainings to all staff that come in direct touch with the passengers. This should include training topics like courtesy, cleanliness, gender sensitivity, trauma response and safety.

x) **Enforcement:** Non-compliance and/or faulty implementation create hazards. Training modules need to raise awareness that codes of practice are executed as per design.

Accessibilty Audits: Training in accessibility audits is an important strategy of ensuring that codes of practice including universal accessibility are followed.

23.6.3 *Skill Development and Training Plan*

Each urban local body should identify one full time training coordinator at the headquarters. He should be provided with suitable support staff and office equipment. The training coordinator should work under the directions of the Municipal Engineer. He should have a complete list of all officers at various levels together with their brief particulars regarding qualifications as also period and area of training received in the last three years. This list should be updated on regular basis to identify the officers who have not been provided training till date. A long term training plan should be prepared which may also include Study Leave for selected individuals to undergo long-term M. Tech. courses in various disciplines of transport planning, traffic engineering and highway engineering. Such a training plan should be prepared under the overall leadership and guidance of the Administrator of the Urban Local Body.

23.6.4 *Funds*

Sufficient funds must be budgeted by the urban local bodies for skill development and training of staff. The quality of output of the skilled staff and efficient delivery of project would more than offset the expenditure incurred towards skill development. It is recommended that the urban local bodies may earmark a provision of 0.25 % of the project cost in each estimate towards skill development and training of staff so as to cover course fees, travel to training centres, per diem allowance and expenses of training institutions in imparting training to the officers. This would help create a pool of talented engineers and other staff within the department.

23.6.5 *Training Infrastructure and Institutional Architecture*

i) Some states already have training institution or centre for providing training to its technical personnel. Other states may also consider setting up a training institute at state level. The state level training institutions may be utilised by these urban bodies for training of engineers responsible for urban roads.

ii) Developing and utilizing the technical training resource reservoirs available in the Centres of Excellence created by the Ministry of Housing and Urban Affairs, Institute of Urban Transport, School of Planning and Architecture (Depatment of Transport Planning), IITs, NITs and other engineering colleges for supporting the state level training centres.

iii) Among the prime training institutions in the country, mention may be made of the Indian Academy of Highway Engineers earlier known as the National Institute for Training of Highway Engineers (NITHE) and the Central Road Research Institute (CRRI) at the national level. The IAHE is a collaborative institute of the Central and State Governments.

iv) Apart from national institutions, there is need to identify international training agencies. Officers both at senior and junior level should be exposed to best international practices by enabling them to visit prestigious projects not only within the country but also abroad. The external agencies like the World Bank, ADB, JICA and other international forums can provide technical assistance support in this effort.

v) Distance education and e-learning are other IT-enabled tools that can be utilized in this sector also.

vi) The training institutions should be in regular contact with the IUT, IRC, CRRI and the academia in identifying the new engineering technologies and innovations and other business processes that need to be introduced for their transfer on the ground. The IRC Committee and IUT on urban roads can act as a focal point for such interaction.

23.6.6 *Training Areas, Modules and Course Material*

There are several areas for training to which the officers need to be exposed. It needs to be realized that the area and depth of training will differ for level of staff (supervisors, junior level, middle level and senior level engineers). Indicative lists of possible areas for skill enhancement of engineers are given in **Annex 22.1**. Some outside support should be sought in preparing a comprehensive document identifying areas of training for:

- Staff at senior, middle and junior level
- Supervisors, Surveyors, Lab. Assistants
- Junior Engineers and Assistant Engineers at Entry Level

Such a document should also provide a brief course content for each topic of training and indicative duration for various levels of staff. Another document should be prepared covering course material for each training module. This should include list of reading references and relevant IRC codes, standards, manuals and guidelines for each module.

23.6.7 *Skill Development of Contractor Managers, Workers and Equipment Operators*

i) Skill Development Mission launched some time back is currently receiving increased attention. It has been recognised that to ensure skills match demand, special efforts are required for the government and the enterprises to play a partnership role in strengthening the ITIs, polytechnics and in quality improvement of the faculty and trainers. Mobilisation of investment in strengthening of ITIs, improving efficiency in running and management of these institutes and post training employment are envisaged to be the primary responsibility of the private sector. The government would facilitate through part financial support and an enabling framework.

ii) The National Skill Development Corporation set up by the Ministry of Finance, Government of India provides funding to build scalable skills and vocational training initiatives. Under this corporation, has been constituted the Construction Skill Development Council of India as a not for profit organisation. The aim of this Council is to develop, establish, standardize and sustain Industry Competency Frameworks, skills levels, occupational standards which are to meet the expectations of the construction industry. Within the construction sector, roads need a special emphasis as most Industrial Training Institutes (ITIs) and Polytechnics have bypassed the needs of the roads sector.

iii) The current Building and other Construction Workers (Regulations of Employment and Conditions of Service) Act, 1996 and accompanying Cess Act, 1996 oblige the state governments to constitute Construction Workers Welfare Board, collect the cess (currently at one percent of the construction cost) and utilize the proceeds for the welfare of the workers registered with such Welfare Boards. It is only logical that part of the proceeds collected under this Act is made available for training of construction workers. Some funds for this purpose could also be tapped from the Corporate Social Responsibility component of the industrialists.

iv) To meet the huge demand for specific skills of a high order in the road construction sector, a Public Private Partnership between state government and industry may be considered to promote skills development programme under the umbrella of the Skill Development Initiative (SDI). This proposed strategy should evolve a new strategic framework for skill development for early school leavers and existing workers, especially in the un-organised sector in close consultation with industry (FICCI, ASSOCHAM, CII, Chamber of Commerce, CIDC, and Contractors and Consultants), construction equipment manufacturers like ICEMA and workers organizations.

Annex 23.1

POSSIBLE AREAS FOR SKILL ENHANCEMENT IN THE ROAD SECTOR

(Engineers of Urban Local Bodies)

1. Current issues in highway sector development, financing and administration.
2. Urbanisation trends, importance of urban transport and urban road infrastructure, concept of master plan for cities, mobility planning concepts.
3. Bus Rapid Transport corridors and planning of road alignment and cross-section to accommodate BRT corridors.
4. Principles of traffic flow and capacity, service level benchmarks for urban roads.
5. Planning of road infrastructure for VRUs and NMT.
6. Traffic and Transportation Studies of Cities – Case Studies.
7. ITS technologies in traffic management and incident management.
8. Feasibility reports and detailed project reports for road projects (DPRs), case studies.
9. Project management by road agencies and supervision consultants, case studies.
10. Contract administration and procurement procedures
    - FIDIC conditions
    - Standard bidding documents.
11. Energy, safety and environment issues in highway sector. Environment management plan. Land management and land acquisition and resettlement and rehabilitation policies for roads.
12. Engineering measures for improving road safety, road signs, pavement markings, crash barriers. Road safety measures at construction sites.
13. Highway legislations: States Highways Act, Motor Vehicles Act, Land Acquisition Act.
14. Pavement design – flexible and rigid pavements, national/international practices, balancing of engineering aspects and resilience to climate change, case studies.
15. Construction and maintenance of flexible pavements.
16. Construction and maintenance of rigid pavements.
17. Design and construction of high embankments, ground improvement techniques, case studies.
18. Soil reinforcement structures – design and construction, case studies.
19. Geo-technical and landslide investigations for highway projects in hill towns; case studies.
20. Geometric design of urban roads, pedestrian facilities, cycle tracks, service roads, walkways.
21. Bridge standards and design of foundations, substructures, superstructures, bridge design software, STAAD, etc., case studies.
22. Design of Intersection, Signals, Rotaries.
23. Modern trends in design and construction of flyovers and interchanges; case studies.

24. Advance analysis and design of bridges.
25. Urban drainage system.
26. Maintenance of roads – planning, norms, financing and institutional issues. Concept of road assets.
27. Maintenance of roads – technical aspects, operational capacity issues and performance based and item rates maintenance contracts.
28. Road maintenance management systems, pavement evaluation techniques, PMS, HDM-4.
29. Bridge inspection and diagnosis of distresses observed, performance evaluation, rehabilitation and strengthening of bridges, bridge management system (BMS).
30. Corridor management; engineering and non-engineering aspects, service to road users, overloading control.
31. Planning, design and operation of expressways in urban areas.
32. Disaster Resilient Measures for roads and bridges.
33. Dispute Resolution Mechanism in contracts.
34. Quality control tests in field and laboratories, soil and material characteristics.
35. Axle load, traffic data, O-D traffic surveys, traffic forecasting techniques.
36. New materials and construction and climate resilient technologies.
37. Construction equipment and its management for highway projects.
38. World Bank and ADB guidelines and procedures for highway projects.
39. Use of ICT, GIS and GPS in highway sector.
40. Specifications for road and bridge works.
41. Standard Data Book.
42. Public private partnerships (PPP) in highway sector, BOT and its variants, Hybrid, EPC contracts, SPVs, financial structuring, experiences in Centre and states, case studies.
43. Model Concession Agreement for PPP projects.
44. Cost-benefit and commercial analysis of highway projects, case studies. Road user costs, quantifying benefits of augmenting road capacity, reducing congestion. Energy Efficiency.
45. Concept of tolls, willingness to pay, open and closed system of tolls, design of toll complexes, electronic toll collection, violation detection.
46. Transparency and governance in delivery of highway projects.
47. Stress management, organizational behaviour, managerial skills.
48. Team working, leadership, values, work culture.
49. Access standards and Sensitization regarding user groups.
50. Streets for All- creative inclusive and sustainable urban road spaces.

REFERENCES

1. AASHTO T 283 2014 Edition, 2014 – Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
2. ALIMCO – Artificial Limbs Manufacturing Corporation of India
3. ASTM B 117 – Test Method of Salt Spray [Fog] Testing
4. ASTM D 1653 – Standard Test Methods for Water Vapor Transmission of Organic Coating Films
5. ASTM D 4060 – Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
6. Australia Green Infrastructure Council (AGIC)
7. AWNZS 4456.5:1997 – Masonry Units and Segmental Pavers
8. Bearings (First Revision)
9. BEE 2012
10. BS 3900 – Methods of test for paints. Index of test methods
11. BS EN 13201-3:2003 – Road lighting. Calculation of performance
12. CAN3-A23 – Concrete Materials and Methods of Concrete
13. CAN3-A23 – Concrete Materials and Methods of Concrete Construction, Standards Council of Canada
14. Census 2011 – Census of India 2011
15. Chennai Master Plan of 2008
16. CROW – Design Manual for Bicycle Traffic
17. EN 1338:2003 – Concrete Paving Blocks – Requirements and Test Methods, 2003, European Committee for Standardization
18. Explosives Rules 1983
19. Guidelines from the Uttarakhand Disaster Recovery Initiative (http://ukdisasterrecovery.in/)
20. HPEC, 2011 – Report on Indian Urban Infrastructure and Services, 2011, High Powered Expert Committee
21. http://www.serb.gov.in/pdfs/brainstormingsessions/DST_Workshop_Final_Report.pdf).
22. IEEE CSE 2016 the 19th IEEE International Conference on Computational Science and Engineering Paris, France, August 24-26, 2016
23. Indian Air Force (http://indianairforce.gov.in/images/IAF_Relief_And_Rescue_Op_Tamilnadu_Dec15/1.jpg)
24. Indian Explosives Act, 1884
25. Inland Waterways Authority of India (IWAI)
26. IRC:5-2015 – Standard Specifications and Code of Practice for Road Bridges, Section-I – General Features of Design (Eighth Revision)

27. IRC:6-2017 – Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Load Combinations (Seventh Revision)
28. IRC:11-2015 – Recommended Practice for the Design and Layout of Cycle Tracks (First Revision)
29. IRC:15-2017 – Code of Practice for Construction of Jointed Plain Concrete Pavements
30. IRC:35-2015 – Code of Practice for Road Markings (Second Revision)
31. IRC:37-2018 – Guidelines for Design of Flexible Pavements (Fourth Revision)
32. IRC:38-1988 – Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision)
33. IRC:58-2015 – Guidelines for the Design of Plain Jointed Rigid Pavements for Highways (Fourth Revision)
34. IRC:65-2017 – Guidelines for Planning and Design of Roundabouts (First Revision)
35. IRC:67-2012 – Code of Practice for Road Signs (Third Revision)
36. IRC:69-1977 – Space Standards for Roads in Urban Areas
37. IRC:73-1980 – Geometric Design Standards for Rural (Non-Urban) Highways
38. IRC:78-2014 – Standard Specifications and Code of Practice for Road Bridges, Section VII – Foundations and Substructures (Revised Edition)
39. IRC:81-1997 – Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique (First Revision)
40. IRC:82-2015 – Code of Practice for Maintenance of Bituminous Surface of Roads (First Revision)
41. IRC:83-2014 (Part IV) – Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings (Spherical and Cylindrical)
42. IRC:86-2018 – Geometric Design Standards for Urban Roads and Streets (First Revision)
43. IRC:89-2019 – Guidelines for Design and Construction of River Training and Control Works for Road Bridges (Second Revision)
44. IRC:92-2017 – Guidelines for Design of Interchanges in Urban Areas (First Revision)
45. IRC:98-2011 – Guidelines on Accommodation of Utility Services on Roads in Urban Areas (Second Revision)
46. IRC:99-2018 – Guidelines for Traffic Calming Measures in Urban and Rural Areas (First Revision)
47. IRC:103-2012 – Guidelines for Pedestrian Facilities (First Revision)
48. IRC:112-2019 – Code of Practice for Concrete Road Bridges (First Revision)
49. IRC:115-2014 – Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements Using Falling Weight Deflectometer (FWD) Technique
50. IRC:119-2015 – Guidelines for Traffic Safety Barriers
51. IRC:120-2015 – Recommended Practice for Recycling of Bituminous Pavements
52. IRC:123-2017 – Guidelines on Geophysical Investigation for Bridges
53. IRC:127-2018 – Guidelines on Skill Development of Workmen in Road Sector

54. IRC:SP:12-2015 – Guidelines for Parking Facilities in Urban Roads" (First Revision)
55. IRC:SP:23-1983 – Vertical Curves for Highways
56. IRC:SP:35-1990 – Guidelines for Inspection and Maintenance of Bridges
57. IRC:SP:41-1994 – Guidelines on Design of At-Grade Intersections in Rural & Urban Areas
58. IRC:SP:50-2013 – Guidelines on Urban Drainage
59. IRC:SP:55-2014 – Guidelines on Traffic Management in Work Zones" (First Revision)
60. IRC:SP:63-2018 – Guidelines for the Use of Interlocking Concrete Block Pavement (First Revision)
61. IRC:SP:65-2018 – Guidelines for Design and Construction of Segmental Bridges (First Revision)
62. IRC:SP:66-2016 – Guidelines for Design of Continuous Bridges (First Revision)
63. IRC:SP:76-2015 – Guidelines for Conventional and Thin Whitetopping (First Revision)
64. IRC:SP:79-2008 – Tentative Specifications for Stone Matrix Asphalt
65. IRC:SP:83-2018 – Guidelines for Maintenance, Repairs & Rehabilitation of Cement Concrete Pavements (First Revision)
66. IRC:SP:91-2019 – Guidelines for Road Tunnels (First Revision)
67. IRC:SP:92-2010 – Road Map for Human Resource Development in Highway Sector
68. IRC:SP:102-2014 – Guidelines for Design and Construction of Reinforced Soil Walls
69. IRC:SP:110-2017 – Application of Intelligent Transport System for Urban Roads
70. IRC:SP:112-2017 – Manual for Quality Control in Road and Bridge works
71. IRC:SP:118-2018 – Manual for Planning and Development of Urban Roads and Streets
72. IS:1566 – Hard-drawn steel wire fabric for concrete reinforcement, 1982, Indian Standard
73. IS:16101 – General Lighting - LEDs and LED Modules - Terms and Definitions
74. IS:16102-1 – Self - Ballasted LED Lamps for General Lighting Services, Part 1: Safety Requirements
75. IS:16102-2 – Self-Ballasted LED Lamps for General Lighting Services, Part 2: Performance Requirements
76. IS:16103-1 – LED Modules for General Lighting, Part 1: Safety Requirements
77. IS:16103-2 – LED modules for general lighting, Part 2: Performance requirements
78. IS :16104: d.c.OR a.c. – Supplied Electronic Control Gear for LED Modules - Performance RequirementsIS 16105:2012
79. IS:16106 – Method of Electrical and Photometric Measurements of Solid State Lighting (LED) Products
80. IS:16107-1 – Luminaires Performance, Part 1: General requirements
81. IS:16107-2-1 – Luminaires performance, Part 2: Particular requirements
82. IS:16108-2012 – Photobiological Safety of Lamps and Lamp Systems
83. IS:1786 – High strength deformed steel bars and wire for concrete, 2008, Indian

Standard

84. IS:1944-1 and 2 – Code of Practice for Lighting of Public Thoroughfare. Part 1 and 2 for main and secondary roads (Group A and B)
85. IS:2386-1 – Methods of Test for Aggregates for Concrete, Part I: Particle Size and Shape
86. IS:2386-3 – Methods of test for aggregates for concrete, Part 3: Specific gravity, density, voids, absorption and bulking
87. IS:2386-4 – Methods of test for aggregates for concrete, Part 4: Mechanical properties
88. IS:2386-5 – Methods of Test for Aggregates for Concrete, Part V: Soundness
89. IS:2720-16 – Methods of test for soils, Part 16: Laboratory determination of CBR
90. IS:2720-28 – Methods of test for soils, Part 28: Determination of dry density of soils, inplace, by the sand replacement method
91. IS:2720-5 – Methods of test for soils, Part 5: Determination of liquid and plastic limit
92. IS:2720-8 – Methods of test for soils, Part 8: Determination of water content-dry density relation using heavy compaction
93. IS:4081-1986 – Safety code for blasting and related drilling operations
94. IS:432 – Mild Steel and Medium Tensile Steel Bars and Hard-Drawn Steel Wire for Concrete Reinforcement, 1982, Indian Standard
95. IS:456 – Plain and Reinforced Concrete - Code of Practice, 2000, Indian Standard
96. IS:4756-1978 – Safety code for tunneling work
97. IS:5640 – Method of test for determining aggregate impact value of soft coarse aggregates
98. IS:6241 – Method of Test for Determination of Stripping Value of Road Aggregates
99. IS:6461-5 – Glossary of terms relating to cement concrete, Part 5: Formwork for concrete
100. IS:15658-2006 – Precast concrete blocks for Paving, 2006, Bureau of Indian Standards 103. IS:2386 (Part I, III, IV, V)
101. IS:2720 (Part 5, 8, 16, and 28)
102. ITDP - Footpath Design – a guide to creating footpaths that are safe, comfortable and easy to use, 2013, Institute for Transportation and Development Policy
103. ITDP and EPC, 2011 – Better Streets, Better Cities – A guide to street design in urban India, 2011, Institute for Transportation and Development Policy, Environmental Planning Collaborative
104. Mines Act, 1952
105. Mines Rules 1955
106. MoRTH Specifications for Road and Bridge Works, 2013 (Fifth Revision)
107. MoRTH, 2016 – Road Transport Yearbook 2015-16, Ministry of Road Transport and Highways
108. MoUD, 2008 – Study on Traffic and Transportation Policies and strategies in Urban Areas in India, 2008, Ministry of Urban Development

109. MoUD, 2014 – Annual Report 2013-14, Ministry of Urban Development

110. NACE RP 0394 – Standard Practice Application, Performance, and Quality Control of Plant-Applied Single-Layer Fusion-Bonded Epoxy External Pipe Coating

111. NAPA, 2003 – National Asphalt Pavement Association

112. National Building Code 2010

113. National Disaster Management Plan (NDMP), 2016

114. National Policy on Disaster Management, 2009

115. NUTP 2014 – National Urban Transport Policy, 2014, Ministry of Urban Development

116. Regulations of Employment and Conditions of Service Act, 1996 and accompanying Cess Act, 1996

117. Timesavers Standards for Landscape Architecture

118. Toshitaka Motoda (No Source Found for the image)

119. USAID ECO-III. 2010. Guidelines Energy Street Lighting. BEE.

120. UTTIPEC 2009 Pedestrian Design Guidelines, Unified Traffic and Transportation Infrastructure Planning & Engineering, DDA, New Delhi

121. WHO, 2011 - Pedestrian Safety – A Road Safety Manual for Decision Makers and Practitioners, 2011, World Health Organization

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)

ISBN 978-93-86512-87-1